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SCIENTIFIC AMERICAN SUPPLEMENT

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VOLUME LXXV]
NUMBER 1939]

NEW YORK, MARCH 1, 1913

[10 CENTS A COPY
$5.00 A YEAR

Olive Bridge Dam—View Looking Up-stream.

THE NEW YORK WATER SUPPLY.—[See page 140.]

Amateur Astronomy*

Valuable Contributions Made by Volunteer Workers in the Field

By W. E. Plummer, M.A., F.R.A.S.

In considering the question of amateur astronomy, I suppose the first question to decide is, Who is an amateur? It is a question which in some direction has, I believe, given anxiety to many, as the borderland separating the amateur from the professional can be a very narrow one. The general idea or definition is that an amateur is a man who takes up science as a hobby, who has other occupations, but finds his relaxation or amusement in some scientific investigation, for which he has had no special outside training. He is usually self-taught in the branch of knowledge which he finally selects for study, and inasmuch as a self-taught man is generally at a disadvantage as compared with those who have enjoyed professional instruction and guidance, the term has, in some instances, come to be regarded as a reproach, an utterly false impression, which I shall do my best to correct. There is, I know, in various walks of life a certain amount of jealousy between the professional and the amateur, a tendency to despise the work of the one as fragmentary and disconnected, as unmethodical and superficial, to which the amateur retorts by complaining that the professional is mechanical, unimaginative, and steeped in routine. I would fain hope that that spirit of ungenerous recognition or mutual dissatisfaction does not exist to any great extent in astronomy. I give you the following reason for the grounds of my belief. If you look down the list of those to whom the medal of the Royal Astronomical Society has been awarded in past years, you will find a considerable number of so-called amateurs. This tells us, or, at least, I think so, that the work of the amateur is not less valuable than that of the professional, and that it is as readily welcomed and recognized. This should be an encouragement to all amateurs to go and do likewise. In the vast field of research there is room for all, and just as amateurs have rendered yeomen's service in the past, so I firmly believe that they will be needed, and will enrich astronomy in the future. And standing here with the wish to inspire all to use their best endeavor, permit me to recall to you in the briefest possible manner the names and the work of some of those who have received this greatest measure of recognition that it is possible for the Society to bestow. In this place, surely the name of Dr. I. Roberts occurs to you, who, though his work in some particulars has been superseded by later workers with improved equipment, revealed to the world that delicacy and complexity of structure in the nebulæ at which we have all marveled, and on which we have all speculated. He enabled the student of the universe to gaze on and scrutinize these ever-beautiful and mysterious objects at his leisure, instead of utilizing those few moments on the finest of nights and uncomfortable surroundings. This, I take it, was his reward, the consciousness that he had given to the world new thoughts and new facts, that inquiry and analysis were easier because he had worked and struggled. Another name equally familiar to you is that of Mr. W. F. Denning, whose perseverance and untiring industry have awakened fresh interest in the subject of meteors. Mr. Denning had great difficulties to contend against, not the least of which was ill health. He was hampered, too, by the cares of an exacting business, and there were other reasons known to some of you which might have depressed his energies. But Mr. Denning ever exhibited that dogged determination which is characteristic of the amateur. Mr. Denning threw all his energies into his self-imposed task, and is a worthy example we should all be proud to imitate, whether in his single-hearted and enthusiastic devotion to the discovery of truth or in rising superior to frowning discouragement and bodily weakness.

Dr. Common is another whose example should prove stimulating and instructive. Long exposure in photography was in its infancy when he was at work in the 'eighties. His early attempts on the nebulæ of Orion were failures. The stars were seen as lines, and the nebulæ proper presented a small and faint stain upon the plate. But such failures were, to the man possessed of the true spirit of the amateur, suggestive of the necessity of improving the driving of the clock and the procuring of a more sensitive plate. He had not only the gratification of present success, but also the consciousness that all those following in his footsteps have entered into his labors. He had the conviction of having accomplished something for the advancement of science, of making its acquisition easier to others. Frank Maclean and Sir W. Huggins are names to hold in fond remembrance as workers in other departments of our science indicating what amateurs have affected in the past, and convincing us that such men, animated by the same motives, and propelled by the same eagerness, will be needed in the future.

Before leaving this part of my subject I would like to make another remark, which may or may nor be relevant. You will notice that all these names are English, and I do not find among the list of medallists any foreigner who, under our rough-and-ready definition, could be classed as an amateur. I do not think that this is accidental; it rather points to some national characteristic, that there is something peculiarly English in amateur astronomy, something that appeals more to Englishmen than to other nations. It would be very interesting if we could discover the explanation of this peculiarity. It can hardly be traced to our climate, for that is sufficiently depressing, nor in the amount of leisure at command, for we are as busy as most nations. Navigation, our pride in the sea, may act as an unconscious incentive; but more probably this taste is due to example. Accident probably led the way. Perhaps the fame and the royal favor that attached to the elder Herschel, himself an amateur, may have induced others to follow in his steps. But, looking to what amateurs have effected in all branches of science, in physics, chemistry, biology and other departments, I am inclined to see a national trait, a distinctive feature, which separates us from all other nations of the world. If this be true, then I say that it is a most precious inheritance, and one to be guarded jealously. The name of "amateur" is one to be cherished, and not to be despised. That is my message to you to-night—to make you esteem more highly the ardent voluntary worker, whose labors, in no insignificant way, have placed English science on the pedestal it occupies. Every nation, owing to a number of circumstances, possesses its own peculiarities which render it better fitted than its neighbors to forward some particular part of the work on which the progress of science depends. Let us encourage each other to take that share of work for which national character and educational training best adapt us. If it be not given to us to imitate the plodding, exact experiment of the German, if the domain of accurate measurement belongs to France, if the *metier* of the American is the production of gigantic apparatus, while our forte lies in voluntary exertion in all branches of science indifferently, it seems probable that the greatest good will be obtained by following the path of least resistance, not by attempting to transplant the methods and imitate the work of other nationalities—in a word, to struggle on, following the lines which have hitherto proved fructiferous. With us, in our scheme of scientific progress, the amateur is one great and necessary factor in the origination of scientific ideas.

Now, the amateur, in the light in which we are considering him here, usually begins his study or research when the mind is sufficiently developed to form an entirely unbiased opinion. One consequence of this, it seems to me, is a great advantage—viz., that we have a section of scientific men beginning their work untrammelled by preconceived notions which a systematic training in science is bound to instill. Whatever is taught in an early age must necessarily be taught in a more or less dogmatic manner, and, in whatever way it is taught, experience shows that it is usually received in a dogmatic spirit. The matured man approaching the subject takes his own course, afraid of neither ridicule nor criticism. His very ignorance is his shield. He has his own view of what he intends to accomplish, and he probably does not know the particular direction or method in which the so-called trained mind would go to work to obtain the needed result. This is not necessarily a disadvantage; indeed, in particular cases it is an advantage. It does not follow that because the amateur pursues his own method he is wrong or inferior. Further, if he possessed a complete knowledge of everything bearing upon a particular subject, he might be discouraged, or consider himself not sufficiently informed. The stimulus of inquiry would be gone. In some cases such knowledge may be essential; in others it is a hindrance. Different types of men incline to different types of research, pursue different methods, and it is well to preserve all variations in the struggle. My point is that a problem or a research cannot be approached in too many ways. Freshness of view, novelty of conception, are the peculiar features that amateurs bring to the task, ignoring the stereotyped methods that have been sanctioned by long usage. To lose or despise those factors which make for success would be a great mistake. They are qualities that need encouragement. I am indebted to Prof. Schuster, who describes an amateur as one who learns his science as he wants it and when he wants it, for the following simile: The engine which works out the great problems of Nature may be likened to a thermodynamic machine. The amateur supplies the steam, and the hidebound professional furnishes the cold water. The former, boiling over with ill-considered and fanciful ideas, does not like the icy douche, and the professional scientist does not like the latent heat of the condensing steam; but, nevertheless, the hotter the steam and the colder the water, the better works the machine. Sometimes it happens that the boiler and the cooler are both contained in the same brain, and each country can boast of a few such in a century; but most of us have to remain satisfied with forming only an incomplete part of the engine of research. Among those who have combined the zeal of the enthusiast and the caution and restraint of the professional scientist, he would place such honored names as those of Faraday and Joule in the army of amateurs—men who would have been impossible in any other country, and who stand so conspicuously above their fellows here, that we have not been accustomed to consider them in this light.

It may be asked at this point whether there is any possibility of losing or diminishing the influence of amateurism as a lever to raise scientific activities. You cannot train a man to be an amateur, but you may deter one who would fill that rôle with satisfaction and success. It would carry me too far to-night to attempt to dissect the causes that may operate injuriously upon the exercise of the talents which peculiarly belong to the amateur. But it is possible one ill-effect may be found in insisting upon too great uniformity in education. To revert to our thermodynamic machine, no work can be got from it when there is no change of temperature. When all bodies are at the same temperature, there may be an unlimited amount of energy present, no part of which is available for transformation. We get no work from still water if it be all at the same level; so, in like manner, we can get no progress from minds that are molded on one pattern and work in one groove. I must not forget the astronomical amateur in considering the general proposition; but I would also like to mention the danger lurking in the tendency to too early specialization in particular directions. Curiosity can be cooled down too early. Forward summers mostly have an early spring, as Shakespeare taught. The brain can become jaded, maturity be too soon reached. The early-trained is apt to think that he has exhausted the sources of knowledge, and that all is vanity. If scientific theories were not taught till a man had reached an age when he was able to form an independent judgment, there would be a greater hope of retaining that originality of ideas, and that diversity in method of work, which I suggest has been a distinguishing feature in the scientific development of this country, and enabled our amateurs to hold a prominent position in the history of investigation.

But I am anxious to keep away from the general amateur, whose analysis is very interesting, to confine myself solely to the part that the amateur plays, or may play, in astronomy. I would, too, look rather on the hopeful and encouraging side than on the depressing and deterrent. I want to impress you with the share that amateur astronomy can take, and is, perhaps, destined to take, in the future. I want especially to convince you that the day of the amateur is not past—that there is still work for him. The conditions of observing may change, the problems may be new, the research may be more recondite and more difficult than formerly; but the amateur is not to be elbowed out of the crowd that is pressing on to the goal; and perhaps the readiest way to win confidence would be to read some words which fell from the Director of the Mount Wilson Observatory, than whom no man is more competent to speak, either on account of his education, his work, or his success. For let me remind you that there was a time when he was an amateur in the ordinary acceptance of the term, and, by the definition I am going to give you presently, you will see that, in the truest and best sense of the word, he remains an amateur still. Moreover, there is a particular fitness in quoting such an authority, for he of all men has revelled in the use of large telescopes. If any man knows the importance of apparatus to which the amateur cannot hope to have access, it is Prof. Hale; but, notwithstanding, or perhaps because of, such knowledge, no man is more eager to assure the owner of small means, the ardent amateur, that there is still work for him. These are his words: "I have sometimes heard it said that the great cost of modern observatories tends to discourage workers with small instruments—observers who are no less interested in the pursuit of astronomical research than the astronomers in large institutions. It seems to me that if there is any serious discouragement, due to this cause, of men

* An address to the Liverpool Astronomical Society.

who are engaged in original research with small telescopes and inexpensive apparatus, it is a question whether large observatories should be established."

Here is a man whose reputation rests on what he has been able to accomplish with large telescopes, who has revealed to us more of the Constitution of the Sun than any living authority, who has used high resolving power and very high linear dispersion, who recognizes that in the future we must be prepared to use even more powerful instruments, and yet he is willing to forego the use of this powerful apparatus if it discourages, if it deprives the man of small means of pursuing science in his own way. And he goes on to give us the reason for this self-denying decision. For at any period in the progress of observational astronomy there are two most important subjects for consideration. One relates to the accomplishment of a great amount of routine observation and the discussion of results, and the other relates to the introduction of new ideas, and to the beginnings of new methods which will make the astronomy of the future. I think we will all admit that the introduction of new ideas is quite as important as the prosecution of routine research, and that if any cause whatsoever tends to discourage the men from whom the new ideas might be likely to proceed, that cause of discouragement should be set aside if possible. You see he does not think it impossible that some amateur, working on original lines, untrammelled by authority and precept, may strike out processes that will render the use of large telescopes unnecessary. In these days we have seen the combination of the photographic plate in connection with very moderate reflectors reveal more than the largest telescopes of thirty years ago would show at the eyepiece. What has not the new thought of the application of photography given us, and can anyone suppose that that is the last of the great thoughts that will revolutionize astronomical science. We should remember, too, that this suggestion of the invigorating force of new ideas comes from a man who, working with small means, invented the method by which photographs are now made of all the prominences visible round the entire circumference of the Sun, with a single exposure, and by which faculæ are clearly shown even in the brightest portions of the Sun's disk. We want someone now possessed of a new thought, gifted with scientific imagination, such as he who would tell us how to record the Coronal surroundings of the Sun at other times than at total eclipse. It is not probable that a large telescope is needed: that is probably not the way it will be done at all. Not by old methods, not by increasing the efficiency of the power in our hands now, will that problem be solved. Only by originality of thought, only by the exercise of powerful imagination will that problem and many others be solved, as they will be solved, not perhaps in my time, but I hope in the near future, by the energy now being expended in research by the younger generation of astronomers.

Slow indeed is progress when measured by what we want to know, and yet never was progress more rapid than during our time, thanks to the efforts of amateurs no less than to professionals. And therefore the director of the great solar observatory, that wonderful focus of activity, in which one hardly knows whether he ought most to admire the exhaustless energy or the admirable ingenuity which he finds displayed, who knows all this and much more, says emphatically: "Therefore, I say in all seriousness that it is a fair question whether large observatories with powerful instrumental equipment should be established if they tend to keep back the man who is pursuing the subject with less expensive appliances, and is introducing, through his careful consideration of the possibilities of research, the new methods which in the process of time will take the place of the old ones."

Believe me, never before had the astronomer so much work—good, hard, yet hopeful work—before him as to-day. He who is leaving the stage feels that he has only begun, and must leave his successors with more to do than his predecessors left him. For every new discovery suggests fresh lines of work and research. It is unsafe to neglect any source of information, unwise not to take advantage of what seems little likely to lead to fruitful results. Only a few years since, the number of small planets that figured in our catalogues was so great that any new discovery was unwelcome, and regarded as a new burden. Then came the discovery of Eros, and a new source of investigation was put before us—a new light thrown on the Cosmos. Prof. Turner reminded us at a recent meeting of the British Association that Pickering discovered an eighth satellite of Saturn, and the discovery led to the recognition of the possibility of retrograde motion. To explain this, we had to revise our views of the past history of the Solar System. Incidentally, by exciting and stimulating curiosity, it led to the curious pair that circulate about Jupiter, and of the extraordinary eighth satellite. Do you think there are no more conquests to be made, no more discoveries to add increasing interest to the science we are met to encourage? The very suggestion of finality is an absurdity. We have mapped out our Solar System with some precision; but what of that great universe of millions of stars in which our Solar System is only a speck of star-dust, a speck which a traveler through the wilds of space might pass a hundred times without notice. We have learned much about this universe, though our knowledge of it is still dim. We see it as a traveler on a mountain-top sees a distant city in a cloud of mist: by a few specks of glimmering light from steeples or roofs. We want to know more about it, its origin and destiny, its limits in time and space, if it has any, what function it serves in that universal economy. The journey is long, yet we want in knowledge at least, as our motto may remind us, to reach the stars. We cannot do ourselves justice, or render any assistance to the scientific aspirations of others if we conceive our duty and our opportunities in any mean and petty spirit. We have to encourage and spur on others in the race. We also serve who only stand and wait. It may be that we play a worthy part by forming an appreciative audience, by supply that stimulus which is necessary to exertion, by creating that atmosphere in which the tender plant of discovery will grow to perfection. It has been said that there are two parties necessary for every advance in science: the one that makes it, and the one that believes in it. Possibly to some of us it is given only to believe; but to most of us it is permitted to take a more active share in the progressive march, especially if we have the true spirit of the amateur in us. And to impress you with what I mean by the real character of the amateur, I cannot do better than quote the definition given by Prof. Hale, who has, I think, spoken so justly of the necessity of cultivating the new ideas and the new methods that the man unfettered by grooves and shibboleths can introduce. "According to my view," he says, "the amateur is the man who works in astronomy because he cannot help it; because he would rather do such work than anything else in the world, and who, therefore, cares little for hampering traditions or for difficulties of any kind." Prof. Turner says of this definition that it provides both an ambition and a criterion. Surely, in this sense, we all want to be amateurs who find it impossible to stop, who work in astronomy because we cannot help it. Clearly the army of amateurs is the right one for the work; weariness cannot touch them; they will go on fighting automatically because they cannot help it. But—oh! those buts!—there are dangers to be feared if the zeal of the amateur outruns his discretion. A little knowledge can be a dangerous thing. It is easy to forget past history, to persuade ourselves that what we have accomplished exceeds in value and importance what has gone before. One may be tempted to seek public support and approval from those who do not possess a right judgment in all things. It is easy in these days to create an applauding public—the party whose belief is necessary for the furtherance of science; but to fill this office and fill fairly it must be an informed public. I think the tendency of the age is to treat with undue leniency every strange and unexpected suggestion, because there is a remote chance that it may contain a germ of truth, a pearl of pure water. Let us remember that a new truth will not suffer ultimately by adverse and even unreasonable criticism, while erroneous theories and false reasoning, supported by the benevolent neutrality of those to whose judgment the scientific world looks for guidance, may be harmful in many ways, especially if they block the way to an independent advance, and encourage hasty and ill-considered generalizations. History is not lacking in examples of this character.

I have spoken to little purpose if you think it is possible for me to suggest the directions in which amateurs may work with advantage. It is originality that is needed, not repetition. I may, in conclusion, point out some of the directions in which more information is required, but the manner in which that information is to be garnered is the true province of the amateur. He must find his work for himself. He will only work untiringly and successfully if he has found the work of the right kind. This he must find for himself. No one, I take it, suggested to Dr. Roberts that the photographing of nebulæ was his *metier*; to Dr. Anderson that he must watch the stars and discover variables with his naked eye. These and many others whose names will occur to you found their work, and happy is he who gets a new thought from his own brain, and one that will last him a lifetime. But I am anxious that you should know that the harvest is plentiful, that there is more work to be done than workers to do it; so that, in conclusion, I will indicate some directions in which leisure may be profitably employed. First of all, let me remind you that there are large departments of astronomical inquiry into which star-gazing does not enter. Much active, valuable work is unconnected with an observatory. An institution which has a local habitation and a magnificent building commands public attention so strongly that earnest work done elsewhere may be overlooked. It cannot be too strongly emphasized that an important part of astronomical work is done away from telescopes and Meridian circles, and requires little more than determination to be successfully followed. I am not speaking now of purely mathematical inquiries. These cannot be followed without years of preparation, which are best surrendered when we are young. But look at such questions as that of star-drift, which is now vexing the astronomical mind. Into this, mathematics scarcely enters. It is a question of comparison and measurement. It is a problem, too, into which new methods can well be introduced by those who are fortunate to have new thoughts, by those who have emancipated themselves, or who have never been under the influence of the elder Herschel—who began the inquiry—Airy, Argelander, Struve, and the host of 19th-century prophets. Consider for a moment how the possibilities of investigation have been enlarged by photography. Hundreds and thousands of stars are recorded on a plate with less difficulty than the positions of a dozen were determined in old times. Certainly the work of a few minutes' exposure of a photographic-plate may take days and weeks for adequate discussion, and remember, further, too, that the directors of many observatories are prepared to place these plates at your service. The comparison of other systems with our own seems a most fructiferous branch of inquiry, offers unlimited capacities. The determination of the absolute dimensions of systems by visual and spectroscopic methods is, too, a promising field. No element now made use of in astronomical research is in a more unsatisfactory state than stellar parallax, and, hence, knowledge that will enable us to improve its determination will be a most welcome contribution to science. The determination of relative masses in stellar systems follows from a knowledge of distance, and how little we know about mass, upon the scale on which the stellar cosmos is built. Variable stars offer most attractive subjects for investigation, and do not require large telescopes. This bugbear of large telescopes, suggesting heavy expenditure, is one that must be coped with. I fully agree with what I have read to you from Prof. Hale, that so far as large telescopes prove a deterrent to many an active brain and mind they are a disadvantage. I cannot put it to you too strongly that each instrument has its particular field of work, in which it can accomplish, or permit to be accomplished, various investigations which are not within reach of other kinds of telescopes. We have too long gone upon the principle of endeavoring to get the biggest telescope we can afford, and then finding work we can do with it. That, I believe, is the wrong way to work. We should first consider what we want to do, and then consider what will be the instrumental means required. By way of illustration, I may point out, though the fact is evident to you, that the beautiful photographs of the Milky Way taken by Prof. Barnard could not have been obtained with the 40-inch Yerkes. He employed a 10-inch Brashear lens of 50-inch focus; not a very expensive instrument, but it was suitable for the work for which it was used. That is the point. If we attempted to photograph the Milky Way with the Yerkes telescope, which no one would be mad enough to attempt, we should get a very small region on a very great scale, but one that would fail to give any notion as to the general distribution of stars in the Galaxy. Again, if we turn to the Sun, it will be readily admitted that photography with large instruments is far behind visual observations in smaller, in revealing the minute structure of sunspots. In some respects, the huge refractors of to-day are unsuitable for the observation of solar prominences. Great focal length here is a disadvantage. If you wish to observe the entire prominence, its image in the focal plane of, say, the Yerkes telescope is so large that the slit cannot be opened wide enough to include the prominence without admitting too much light from the sky. For a study of the general characteristics of prominences, the small instrument has a great advantage over the large one. I could go on to many other instances, but it would be useless.

The conclusion would be the same—that there is work for all instruments if the amateur only has the wit to discover it.

One other remark I might make. Some think that situation defeats the end of astronomical investigation, that the bustle and tremor and electric light of a great city do not favor astronomical research, that undisturbed atmosphere and dark skies are the only conditions under which good work can be accomplished. Such excuses may avail the dillettante astronomer; they do not touch the true amateur, who works because he cannot help it. Remember the faintest satellite of Jupiter was discovered at Greenwich, a close suburb of the smokiest and foggiest metropolis of the world. But I do not look for amateurs to rise from villages and from a stagnant life with the same freedom as from centers of industrial activity. Wealth is necessary to progress in knowledge and the liberal arts. It is only when men are relieved from the necessity of devoting their energies to the immediate wants of life that they can lead intellectual lives. We should, therefore, look to the more enterprising commercial centers of the country as the likeliest source for providing energetic work and true advancement for the amateur.

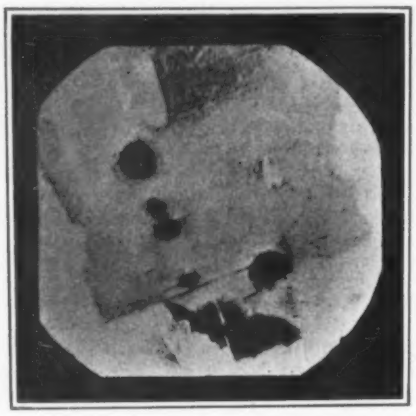


Fig. 1.—Uranium and Radium Halos in One Rock Specimen (Uranium Halo on Right.)

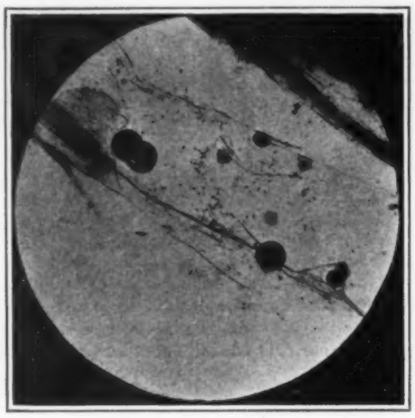


Fig. 2.—Concentric Halos Produced by Radium *A* and Radium *C*.

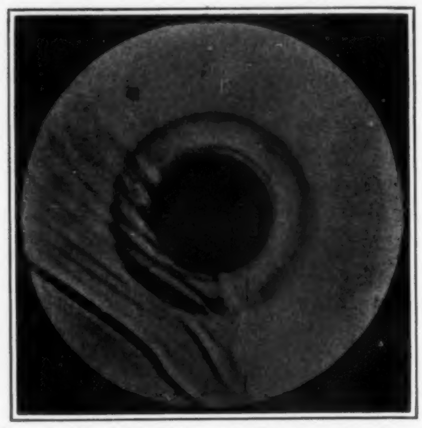


Fig. 3.—Greatly Enlarged Photograph Showing Several Concentric Halos.

Halos in Minerals*

Markings Due to Radium in Rocks, and Their Significance

By J. Joly, F.R.S.

It is now well established that a helium atom is expelled from certain of the radioactive elements at the moment of transformation. The helium atom or alpha ray leaves the transforming atom with a velocity which varies in the different radioactive elements, but which is always very great, attaining as much as 2×10^9 centimeters per second; a velocity which, if unchecked, would carry the atom round the earth in less than two seconds. The alpha ray carries a positive charge of double the ionic amount.

When an alpha ray is discharged from the transforming element into a gaseous medium its velocity is rapidly checked and its energy absorbed. A certain amount of energy is thus transferred from the transforming atom to the gas. We recognize this energy in the gas by the altered properties of the latter; chiefly by the fact that it becomes a conductor of electricity. The mechanism by which this change is effected is in part known. The atoms of the gas, which appear to be freely penetrated by the alpha ray, are so far dismembered as to yield charged electrons or ions; the atoms remaining charged with an equal and opposite charge. Such a medium of free electric charges becomes a conductor of electricity by convection when an electromotive force is applied. The gas also acquires other properties in virtue of its ionization. Under certain conditions it may acquire chemical activity and new combinations may be formed or existing ones broken up. When its initial velocity is expended the helium atom gives up its properties as an alpha ray and thenceforth remains possessed of the ordinary varying velocity of thermal agitation. Bragg and Kleeman and others have investigated the career of the alpha ray when its path or range lies in a gas at ordinary or obtainable conditions of pressure and temperature. We will review some of the facts ascertained.

	Cms.		Cms.
Uranium 1	2.50	Thorium X	4.30
Uranium 2	2.90	Th Emanation	5.00
Ionium	3.00	Thorium A	5.70
Radium	3.30	Thorium C_1	4.80
Ra Emanation	4.16	Thorium C_2	8.60
Radium A	4.75	Radioactinium	4.60
Radium C	6.94	Actinium X	4.40
Radium F	3.77	Act Emanation	5.70
Thorium	2.72	Actinium A	6.50
Radiothorium	3.87	Actinium C	5.40

* Being the Huxley Lecture, delivered at the University of Birmingham on October 30th, 1912, and published in *Bedrock*.

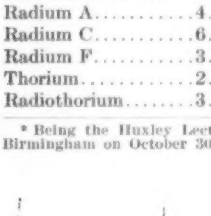


Fig. 5.

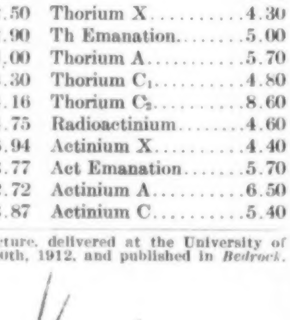


Fig. 6.

Fig. 5.—Curve showing ionization produced by α-rays at different points along their path.

Fig. 6.—Paths of α-rays, showing deflection near end of path.

The range or distance traversed in a gas at ordinary pressures is a few centimeters. The foregoing table, compiled by Geiger, gives the range in air at the temperature of 15 deg. Cent.

It will be seen that the ray of greatest range is that proceeding from thorium C_2, which reaches a distance of 8.6 centimeters. In the uranium family the fastest ray is that of radium C. It attains 6.94 centimeters. There is thus an appreciable difference between the ultimate distances traversed by the most energetic rays of the two families. The shortest ranges are those of uranium 1 and 2.

The ionization effected by these rays is by no means uniform along the path of the ray. By examining the conductivity of the gas at different points along the path of the ray, the ionization at these points may be determined. At the limits of the range the ionization ceases. In this manner the range is, in fact, determined. The dotted curve (Fig. 5) depicts the recent investigation of the ionization effected by a sheaf of parallel rays of radium C in air, as determined by Geiger. The range is laid out horizontally in centimeters. The numbers of ions are laid out vertically. The remarkable nature of the results will be at once apparent. We should have expected that the ray at the beginning of its path, when its velocity and kinetic energy were greatest, would have been more effective than toward the end of its range when its energy had almost run out. But the curve shows that it is just the other way. The lagging ray, about to resign its ionizing properties, becomes a much more efficient ionizer than it was at first. The maximum efficiency is, however, in the case of a bundle of parallel rays, not quite at the end of the range, but about half a centimeter from it. The increase to the maximum is rapid, the fall from the maximum to nothing is much more rapid.

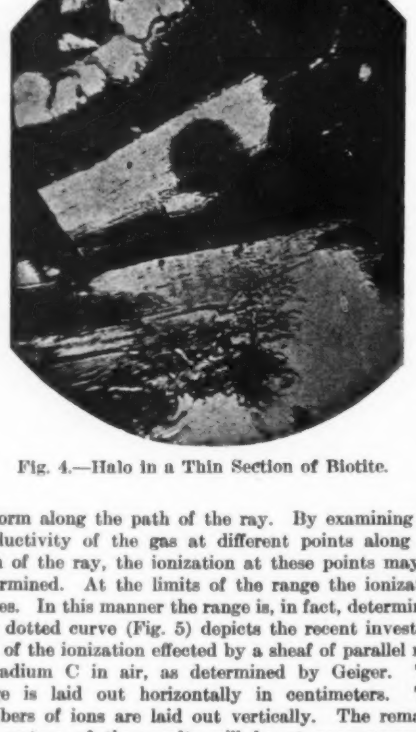


Fig. 4.—Halo in a Thin Section of Biotite.

It can be shown that the ionization effected anywhere along the path of the ray is inversely proportional to the velocity of the ray at that point. But this evidently does not apply to the last 5 or 10 millimeters of the range where the rate of ionization and of the speed of the ray change most rapidly. To what are the changing properties of the rays near the end of their path to be ascribed? It is only recently that this matter has been elucidated.

When the alpha ray has sufficiently slowed down, its power of passing right through atoms, without appreciably experiencing any effects from them, diminishes. The opposing atoms begin to exert an influence on the path of the ray, deflecting it a little. The heavier atoms will deflect it most. This effect has been very successfully investigated by Geiger. It is known as "scattering." The angle of scattering increases rapidly with the decrease of velocity. Now the effect of the scattering will be to cause some of the rays to complete their ranges or, more accurately, to leave their direct line of advance a little sooner than others. In the beautiful experiments of C. T. R. Wilson we are enabled to obtain ocular demonstration of the scattering. The photograph (Fig. 6), which I owe to the kindness of Mr. Wilson, shows the deflection of the ray toward the end of its path. In this case the path of the ray has been rendered visible by the condensation of water particles under the influence of the ionization; the atmosphere in which the ray travels being in a state of supersaturation with water vapor at the instant of the passage of the ray. It is evident that if we were observing the ionization along a sheaf of parallel rays, all starting with equal velocity, the effect of the bending of some of the rays near the end of their range must be to cause a decrease in the aggregate ionization near the very end of the ultimate range. For in fact some of the rays complete their work of ionizing at points in the gas before the end is reached. This is the cause, or at least an important contributory cause, of the decline in the ionization near the end of the range, when the effects of a bundle of rays are being observed. The explanation does not suggest that the ionizing power of any one ray is actually diminished before it finally ceases to be an alpha ray.

The full line in Fig. 5 gives the ionization curve which it may be expected would be struck out by a single alpha ray. In it the ionization goes on increasing till it abruptly ceases altogether, with the entire loss of the initial kinetic energy of the particle.

A highly remarkable fact was found out by Bragg. The effect of the atom traversed by the ray to check the velocity of the ray is independent of the physical and chemical condition of the atom. He measured the "stopping power" of a medium by the distance the ray can penetrate into it compared with the distance to which it can penetrate in air. The less the ratio the greater the stopping power. The stopping power of a substance is proportional to the square root of its atomic weight. The stopping power of an

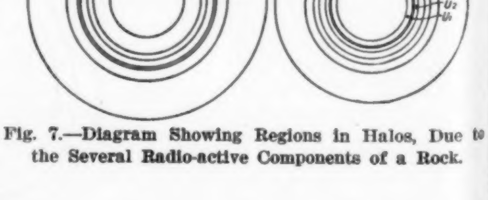


Fig. 7.—Diagram Showing Regions in Halos, Due to the Several Radio-active Components of a Rock.

atom is not altered if it is in chemical union with another atom. The atomic weight is the one quality of importance. The physical state, whether the element is in the solid, liquid or gaseous state, is unimportant. And when we deal with molecules the stopping power is simply proportional to the sum of the square roots of the atomic weights of the atoms entering into the molecule. This is the "additive law," and it obviously enables us to calculate what the range in any substance of known chemical composition and density will be, compared with its range in air.

This is of special importance in connection with phenomena we have presently to consider. It means that, knowing the chemical composition and density of any medium whatsoever, solid, liquid or gaseous, we can calculate accurately the distance to which any particular alpha ray will penetrate. Nor have the temperature and pressure to which the medium is subjected any influence save in so far as they may affect the proximity of one atom to another. The retardation of the alpha ray in the atom is not affected.

This valuable additive law cannot, however, in strictness be applied to the amount of ionization attending the ray. The form of the molecule, or more generally its volume, may have an influence upon this. Bragg draws the conclusion, from this fact as well as from the notable increase of ionization with loss of speed, that the ionization is dependent upon the time the ray spends in the molecule. The energy of the ray is, indeed, found to be less efficient in producing ionization in the smaller atoms.

Before leaving our review of the general laws governing the passage of alpha rays through matter, a point of interest must be referred to. We have hitherto spoken in general terms of the fact that ionization attends the passage of the ray. We have said nothing as to the nature of the ionization so produced. But in point of fact the ionization due to an alpha ray is *sui generis*. A glance at one of Wilson's photographs (Fig. 6) illustrates this. The white streak of water particles marks the path of the ray. The ions produced are evidently closely crowded along the track of the ray. They have been called into existence in a very minute instant of time. Now we know that ions of opposite sign if left to themselves recombine. The rate of recombination depends upon the product of the number of each sign present in unit volume. Here the numbers are very great and the volume very small. The ionic density is therefore high, and recombination very rapidly removes the ions after they are formed. We see here a peculiarity of the ionization effected by alpha rays. It is linear in distribution and very local. Much of the ionization in gases is again undone by recombination before diffusion leads to the separation of the ions. This "initial recombination" is greatest toward the end of the path of the ray where the ionization is a maximum. Here it may be so effective that the form of the curve is completely lost unless a very large electromotive force is used to separate the ions when the ionization is being investigated.

We have now reviewed recent work at sufficient length to understand something of the nature of the most important advance ever made in our knowledge of the atom. Let us glance briefly at what we have learned. The radioactive atom in sinking to a lower atomic weight casts out with enormous velocity an atom of helium. It thus loses a definite portion of its mass and of its energy. Helium which is chemically one of the most inert of the elements, is, when possessed of such great kinetic energy, able to penetrate and ionize the atoms which it meets in its path. It spends its energy in the act of ionizing them, coming to rest, when it moves in air, in a few centimeters. Its particular initial velocity depends upon which of the radioactive elements has given rise to it. The length of its path is therefore different according to the radioactive element from which it proceeds. The retardation which it experiences in its path depends entirely upon the atomic weight of the atoms which it traverses. As it advances in its path its effectiveness in ionizing the atom rapidly increases and attains a very marked maximum. In a gas the ions produced being much crowded together recombine rapidly; so rapidly that the actual ionization may be quite concealed unless a sufficiently strong electric force is applied to separate them. Such is a brief summary of the climax of radioactive discovery; the birth, life and death of the alpha ray. Its advent into science has altered fundamentally our conception of matter. It is fraught with momentous bearings upon geological science. How the work of the alpha ray is sometimes recorded visibly in the rocks and what we may learn from that record I propose now to bring before you.

In certain minerals, notably the brown variety of mica known as biotite, the microscope reveals minute circular marks occurring here and there, quite irregularly. The most usual appearance is that of a circular area darker in color than the surrounding mineral. The radii of these little disk-shaped marks when well defined are found to be remarkably uniform, in some cases four hundredths of a millimeter and in others three hundredths, about. These are the measurements in biotite. In other minerals the measurements are not quite the same as in biotite. Such minute objects are quite invisible to the naked eye. In some rocks they are very abundant, indeed they may be crowded together in such numbers as to darken the color of the mineral containing them. They have long been a mystery to petrologists.

Close examination shows that there is always a small speck of a foreign body at the center of the circle, and it is often possible to identify the nature of this central substance, small though it be. Most generally it is found to be the mineral zircon. Now this mineral was shown by Strutt to contain radium in quantities much exceeding those found in ordinary rock substances. Some other mineral may occasionally form the nucleus, but we never find any which is not known to be specially likely to contain a radioactive substance. Another circumstance we notice. The smaller this central

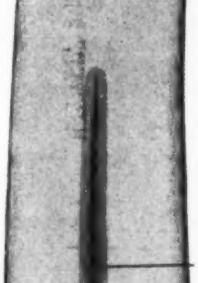


Fig. 8.—An "Artificial" Halo in a Glass Tube Containing Radium Emanation.

nucleus the more perfect in form is the darkened circular area surrounding it. When the circle is very perfect and the central mineral clearly defined at its center we find by measurement that the radius of the darkened area is generally 0.033 millimeter. It may sometimes be 0.040 millimeter. These are always the measurements in biotite. In other minerals the radii are a little different.

We see in the photograph (Fig. 4), much magnified, a halo contained in biotite. We are looking at a region in a rock section, the rock being ground down to such

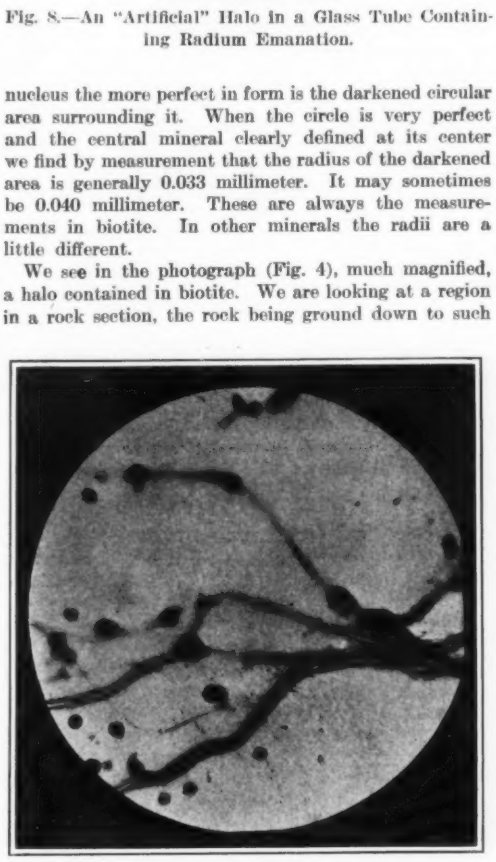


Fig. 9.—"Tubular" Halos Produced by the Flow of Radio-active Solution Along Mineral Veins.

a thickness that light freely passes through it. The biotite is in the center of the field. Quartz and felspar surround it. The rock is a granite. The biotite is not all one crystal. Two crystals, mutually inclined, are cut across. The halo extends across both crystals, but owing to the fact that polarized light is used in taking the photograph it appears darker in one crystal than in the other. We see the zircon which composes the nucleus. The fine lineated appearance of the biotite is due to the cleavage of that mineral, which is cut across in the section.

The question arises whether the darkened area surrounding the zircon may not be due to the influence of the radioactive substances contained in the zircon. The extraordinary uniformity of the radial measurements of perfectly formed haloes (to use the name by which they have long been known) suggests that they may be the result of alpha radiation. For in that case, as we have seen, we can at once account for the definite radius as simply representing the range of the ray in biotite. The furthest-reaching ray will define the radius of the halo. In the case of the uranium family this will be radium C, and in the case of thorium it will be thorium C. Now here we possess a means of at once confirming or rejecting the view that the halo is a radioactive phenomenon and occasioned by alpha radiation; for we can calculate what the range of these rays will be in biotite, availing ourselves of Bragg's additive law, already referred to. When we make this calculation we find that radium C just penetrates 0.033 millimeter and thorium C 0.040 millimeter. The proof is complete that we are dealing with the effects of alpha rays. Observe now that not only is the coincidence of measurement and calculation a proof of the view that alpha radiation has occasioned the halo, but it is a very complete verification of the important fact stated by Bragg, that the stopping power depends solely on the atomic weight of the atoms traversed by the ray.

We have seen that our examination of the rocks reveals only the two sorts of halo, the radium halo and the thorium halo. This is not without teaching. For why not find an actinium halo? Now Rutherford long ago suggested that this element and its derivatives were probably an offspring of the uranium family; a side branch, as it were, in the formation of which relatively few transforming atoms took part. On Rutherford's theory then, actinium should always accompany uranium and radium, but in very subordinate amount. The absence of actinium halos clearly supports this view. For if actinium was an independent element we would be sure to find actinium halos. The difference in radius should be noticeable. If, on the other hand, actinium was always associated with uranium and radium, then its effects would be submerged in those of the much more potent effects of the uranium series of elements.

It will have occurred to you already that if the radioactive origin of the halo is assured the shape of a halo is not really circular, but spherical. This is so. There is no such thing as a disk-shaped halo. The halo is a spherical volume containing the radioactive nucleus at its center. The true radius of the halo may, therefore, only be measured on sections passing through the nucleus.

In order to understand the mode of formation of a halo we may profitably study on a diagram the events which go on within the halo-sphere. Such a diagram is seen in Fig. 7. It shows to relatively correct scale the limiting range of all the alpha-ray producing members of the uranium and thorium families. We know that each member of a family will exist in equilibrium amount within the nucleus possessing the parent element. Each alpha ray leaving the nucleus will just attain its range and then cease to affect the mica. Within the halo-sphere, there must be, therefore, the accumulated effects of the influences of all the rays. Each has its own sphere of influence, and the spheres are all concentric.

The radii in biotite of the several spheres are given in the following table:

Uranium Family.	mm.	Thorium Family.	mm.
Radium C	0.0330	Thorium C_2	0.040
Radium A	0.0224	Thorium A	0.026
Ra Emanation	0.0196	Th Emanation	0.023
Radium F	0.0177	Thorium C_1	0.022
Radium	0.0156	Thorium X	0.020
Ionium	0.0141	Radiothorium	0.019
Uranium 1	0.0137	Thorium	0.013
Uranium 2	0.0118		

In the photograph (Fig. 1) we see a uranium and a thorium halo in the same crystal of mica. The mica is contained in a rock-section and is cut across the cleavage. The effects of thorium C_2 are clearly shown as a lighter border surrounding the accumulated inner darkening due to the other thorium rays. The uranium halo (to the right) similarly shows the effects of radium C, but less distinctly.

Halos which are uniformly dark all over as described above are, in point of fact, "over-exposed;" to borrow a familiar photographic term. Halos are found which show much very beautiful internal detail. Too vigorous action obscures this detail just as detail is lost in an over-exposed photograph. We may again have "under-exposed" halos in which the action of the several rays is incomplete or in which the action of certain of the rays has left little if any trace. Beginning at the most under-exposed halos we find circular dark marks having the radius 0.012 or 0.013 millimeter. These halos are due to uranium although their inner darkening is doubtless aided by the passage of rays which were too few to extend the darkening beyond the vigorous effects of the two uranium rays. Then we find halos carried out to the radii 0.016, 0.018, and 0.019 millimeter. The last sometimes show very beautiful outer rings having radial dimensions such as would be pro-

duced by radium A and radium C. Finally we may have halos in which interior detail is lost so far out as the radius due to emanation or radium A, while outside this floats the ring due to radium C. Certain variations of these effects may occur, marking, apparently, different stages of exposure. Figs. 2 and 3 illustrate some of these stages; the latter photograph being greatly enlarged to show clearly the halo-sphere of radium A.

In most of the cases referred to above the structure evidently shows the existence of concentric spherical *shells* of darkened biotite. This is a very interesting fact. For it proves that in the mineral the alpha ray gives rise to the same increased ionization toward the end of its range as Bragg determined in the case of gases. And we must conclude that the halo in every case grows in this manner. A spherical shell of darkened biotite is first produced and the inner coloration is only effected as the more feeble ionization along the track of the ray in course of ages gives rise to sufficient alteration of the mineral. This more feeble ionization is, near the nucleus, enhanced in its effects by the fact that there all the rays combine to increase the ionization and, moreover, the several tracks are there crowded by the convergency to the center. Hence the most elementary haloes seldom show definite rings due to uranium, etc., but appear as embryonic disk-like markings. The photographs reproduced herewith illustrate many of the phases of halo development. Rutherford succeeded in making a halo artificially by compressing into a capillary glass tube a quantity of the emanation of radium. As the emanation decayed the various derived products came into existence and all the several alpha rays penetrated the glass; darkening the walls of the capillary out to the limit of the range of radium C in glass. Fig. 8 is a magnified view of the tube. The dark central part is the capillary. The tubular halo surrounds it. This experiment has, however, been anticipated by some scores of millions of years, for the same effect is seen in the biotite crystal shown in Fig. 9. Along what are apparently tubular passages or cracks in the mica, a solution, rich in radioactive substances, has moved; probably during the final consolidation of the granite in which the mica occurs. A continuous and very regular halo has developed along these conduits. A string of halo-spheres may lie along such passages. We must infer that solutions or gases able to establish the radioactive nuclei moved along these conduits, and we are entitled to ask if all the halos in this biotite are not, in this sense, of secondary origin. There is, I may add, much to support such a conclusion.

It must not be thought that the under-exposed halo is a recent creation. By no means. All are old, appallingly old; and in the same rock all are, probably, of the same, or nearly the same, age. The under-exposure is simply due to a lesser quantity of the radioactive elements in the nucleus. They are under-exposed, in short, not because of lesser duration of exposure, but because of insufficient action; as when in taking a photograph the stop is not open enough for the time of the exposure.

The halo has, so far, told us that the additive law is obeyed in solid media and that the increased ionization attending the slowing down of the ray obtaining in gases also obtains in solids; for, otherwise, the halo would not commence its development as a spherical shell or envelope. But here we learn that there is probably a certain difference in the course of events attending the immediate passage of the ray in the gas and in the solid. In the former initial recombination may obscure the intense ionization near the end of the range. We can only detect the true end effects by artificially separating the ions by a strong electric force. If this recombination happened in the mineral we should not have the concentric spheres so well defined as we see them to be. What, then, hinders the initial recombination in the solid? The answer probably is that the newly formed ion is instantly used up in a fresh chemical combination. Nor is it free to change its place as in the gas. There is simply a new equilibrium brought about by its sudden production. In this manner the conditions in the complex molecule of biotite, tourmaline, etc., may be quite as effective in preventing initial recombination as the most effective electric force we could apply. The final result is that we find the Bragg curve reproduced most accurately in the delicate shading of the rings making up the perfectly exposed halo.

That the shading of the rings reproduces the form of the Bragg curve, projected, as it were, upon the line of advance of the ray and reproduced in depth of shading, shows that in yet another particular the alpha ray behaves much the same in the solid as in the gas. A careful examination of the outer edge of the circles always reveals a steep but not abrupt cessation of the action of the ray. Now Geiger has investigated and proved the existence of scattering of the alpha ray by solids. We may, therefore, suppose with much probability that there is the same scattering within the mineral near the end of the range. The heavy iron atom of the biotite is, doubtless, chiefly responsible for this in biotite halos. I may observe that this shading of the outer bounding surface of the sphere of action is found however minute the central nucleus. In the case of a nucleus of considerable size another effect comes in which tends to produce an enhanced shading. This will result if rays proceed from different depths in the nucleus. If the nucleus was of the same density and atomic weight as the surrounding mica, there would be little effect. But its density and molecular weight are generally greater, hence the retardation is greater, and rays proceeding from deep in the nucleus experience more retardation than those which proceed from points near to the surface. The distances reached by the rays in the mica will vary accordingly, and so there will be a gradual cessation of the effects of the rays.

The result of our study of the halo may be summed up in the statement that in nearly every particular we have the phenomena which have been measured and observed in the gas reproduced on a minute scale in the halo. Initial recombination seems, however, to be absent or diminished in effectiveness; probably because of the new stability instantly assumed by the ionized atoms.

One of the most interesting points about the halo remains to be referred to. The halo is always uniformly darkened all round its circumference and is perfectly spherical. Sections, whether taken in the plane of cleavage of the mica or across it, show the same exactly circular form, and the same radius. Of course, if there was any appreciable increase of range along or across the cleavage the form of the halo on the section across the cleavage should be elliptical. The fact that there is no measurable ellipticity is, I think, one which would not on first consideration be expected.

For what are the conditions attending the passage of the ray in a medium such as mica? According to crystallographic conceptions we have here an orderly arrangement of molecules, the units composing the crystal being alike in mass, geometrically spaced, and polarized as regards the attractions they exert one upon another. Mica, more especially, has the cleavage phenomenon developed to a degree which transcends its development in any other known substance. We can cleave it and again cleave it till its flakes float in the air, and we may yet go on cleaving it by special means till the flakes no longer reflect visible light. And not less remarkable is the uniplanar nature of its cleavage. There is little cleavage in any plane but the one, although it is easy to show that the molecules in the plane of the flake are in orderly arrangement and are more easily parted in some directions than in others. In such a medium beyond all others we must look with surprise upon the perfect sphere struck out by the alpha rays, because it seems certain that the cleavage is due to lesser attraction, and, probably, further spacing of the molecules, in a direction perpendicular to the cleavage.

It may turn out that the spacing of the molecules will influence but little the average number per unit distance encountered by rays moving in divergent paths. If this is so we seem left to conclude that in spite of its unequal and polarized attractions there is equal retardation and equal ionization in the molecule in whatever direction it is approached. Or, again, if the encounters indeed differ in number, then some compensating effect must exist whereby a direction of lesser linear density involves greater stopping power in the molecule encountered, and *vice versa*.

The nature of the change produced by the alpha rays is unknown. But the formation of the halo is not, at least in its earlier stages, attended by destruction of the crystallographic and optical properties of the medium. The optical properties are unaltered in nature but increased in intensity. This applies till the halo has become so darkened that light is no longer transmitted under the conditions of thickness obtaining in rock sections. It is well known that there is in biotite a maximum absorption of a plane polarized light ray when the plane of vibration coincides with the plane of cleavage. A section across the cleavage then shows a maximum amount of absorption. A halo seen on this section simply produces this effect in a more intense degree. This is well shown in Fig. 4 on a portion of the halo-sphere. The descriptive name "Pleochroic Halo" has originated from this fact. We must conclude that the effect of the ionization due to the alpha ray has not been to alter fundamentally the conditions which give rise to the optical properties of the medium. The increased absorption is probably associated with some change in the chemical state of the iron present. Halos are, I believe, not found in minerals from which this element is absent. One thing is quite certain. The coloration is not due to an accumulation of helium atoms, i. e., of spent alpha rays. The evidence for this is conclusive. If helium was responsible we should have halos produced in all sorts of colorless minerals. Now we sometimes see zircons in felspars and in quartz, etc., but in no such case is a halo produced. And halo-spheres formed within and sufficiently close to the edge of a crystal of mica are abruptly truncated by neighboring areas of felspar or quartz, although we know that the rays must pass freely across the boundary. Again it is easy to show that even in the oldest halos the quantity of helium involved is so small that one might say the halo-sphere was a tolerably good vacuum as regards helium. There is, finally, no reason to suppose that the imprisoned helium would exhibit such a coloration, or, indeed, any at all.

I have already referred to the great age of the halo. Halos are not found in the younger igneous rocks. It is probable that a halo less than a million years old has never been seen. This, *prima facie*, indicates an extremely slow rate of formation. And our calculations quite support the conclusions that the growth of a halo, if this has been uniform, proceeds at a rate of almost unimaginable slowness.

Let us calculate the number of alpha rays which may have gone to form a halo in the Devonian granite of Leinster.

It is common to find haloes developed perfectly in this granite, and having a nucleus of zircon less than 5×10^{-4} centimeters in diameter. The volume of zircon is 65×10^{-12} cubic centimeters and the mass 14×10^{-12} grammes; and if there was in this zircon 10^{-8} grammes radium per gramme (a quantity about five times the greatest amount measured by Strutt), the mass of radium involved is 14×10^{-20} grammes. From this and from the fact ascertained by Rutherford that the number of alpha rays expelled by a gramme of radium in one second is 3.4×10^{10}, we find that *one* ray is shot from the nucleus in a year. If now, geological time since the Devonian is fifty millions of years, then fifty millions of rays built up the halo. If geological time since the Devonian is 400 millions of years, then 400 millions of alpha rays are concerned in its genesis. The number of ions involved, of course, greatly exceeds these numbers. A single alpha ray fired from radium C will produce 2.37×10^{5} ions in air.

But haloes may be found quite clearly defined and fairly dark out to the range of the emanation ray and derived from much lesser quantities of radioactive materials. Thus a zircon nucleus with a diameter of but 3.4×10^{-4} centimeters formed a halo strongly darkened within, and showing radium A and radium C as clear smoky rings. Such a nucleus, on the assumption made above as to its radium content, expels one ray in three years. But, again, haloes are observed with less blackened pupils and with faint ring due to radium C, formed round nuclei of rather less than 2×10^{-4} centimeters diameter. Such nuclei would expel one ray in sixteen years. And even lesser nuclei will generate in these old rocks haloes with their earlier characteristic features clearly developed. In the case of the most minute nuclei, if my assumption as to the uranium content is correct, an alpha ray is expelled, probably, no oftener than once in a century; and possibly at still longer intervals.

The equilibrium amount of radium contained in some nuclei may amount to only a few atoms. Even in the case of the larger nuclei and more perfectly developed halos the quantity of radium involved is many millions of times less than the least amount we can recognize by any other means. But the delicacy of the observation is not adequately set forth in this statement. We can not only tell the nature of the radioactive family with which we are dealing; we can recognize the presence of some of its constituent members. I may say that it is not probable the zircons are richer in radium than I have assumed. My assumption involves about 3 per cent of uranium. I know of no analyses ascribing so great an amount of uranium to zircon. The variety cyrtolite has been found to contain half this amount, about. But even if we doubled our estimate of radium content, the remarkable nature of our conclusions is hardly lessened.

It may appear strange that the ever-interesting question of the earth's age should find elucidation from the study of halos. Nevertheless the subjects are closely connected. The circumstances are as follows: Geologists have estimated the age of the earth since denudation began, by measurements of the integral effects of denudation. These methods agree in showing an age of about 10^{8} years. On the other hand, measurements have been made of the accumulation in minerals of radioactive *débris*, the helium and lead, and results obtained which, although they do not agree very well among themselves, are concordant in assigning a very much greater age to the rocks. If the radioactive estimate is correct, then we are now living in a time when the denudative forces of the earth are about eight or nine times as active as they have been on the average over the past. Such a state of things is absolutely unaccountable. And all the more unaccountable be-

cause from all we know we would expect a somewhat *lesser* rate of solvent denudation as the world gets older and the land gets more and more loaded with the washed-out materials of the rocks.

Both the methods referred to of finding the age assume the principle of uniformity. The geologist contends for uniformity throughout the past physical history of the earth. The physicist claims the like for the change rates of the radioactive elements. Now the study of the rocks enables us to infer something as to the past history of our globe. Nothing is, on the other hand, known respecting the origin of uranium or thorium, the parent radioactive bodies. And while not questioning the law and regularity which undoubtedly prevail in the periods of the members of the radioactive families, it appears to me that it is allowable to ask if the change rate of uranium has been always what we now believe it to be. This comes to much the same thing as supposing that atoms possessing a faster change rate once were associated with it which were capable of yielding both helium and lead to the rocks. Such atoms might have been collateral in origin with uranium from some antecedent element. Like helium, lead may be a derivative from more than one sequence of radioactive changes. In the present state of our knowledge the possibilities are many. The change rate is known to be connected with the range of the alpha ray expelled by the transforming element; and the conformity of the halo with our existing knowledge of the ranges is reason for assuming that, whatever the origin of the more active associate of uranium, this passed through similar elemental changes in the progress of its disintegration. There may, however, have been differences in the ranges which the halo would not reveal. It is remarkable that uranium at the present time is apparently responsible for two alpha rays of very different ranges. If these proceed from different elements, one should be faster in its change rate than the other. Some guidance may yet be forthcoming from the study of the more obscure problems of radioactivity.

Now it is not improbable that the halo may contribute directly to this discussion. We can evidently attack the biotite with a known number of alpha rays and determine how many are required to produce a certain intensity of darkening, corresponding to that of a halo with a nucleus of measurable dimensions. On certain assumptions, which are correct within defined limits, we can calculate, as I have done above, the number of rays concerned in forming the halo. In doing so we assume some value for the age of the halo. Let us take the maximum radioactive value. A halo originating in Devonian times may attain a certain central blackening from the effects of, say, 10^8 rays. But now suppose we find that we cannot produce the same degree of blackening with this number of rays applied in the laboratory. What are we to conclude? I think there is only the one conclusion open to us, that some other source of alpha rays, or a faster rate of supply, existed in the past. And this conclusion would explain the absence of halos from the younger rocks; which, in view of the vast range of effects possible in the development of halos, is, otherwise, not easy to account for. It is apparent that the experiment on the biotite has a direct bearing on the validity of the radioactive method of estimating the age of the rocks. It is now being carried out by Prof. Rutherford under reliable conditions.

Finally, there is one very certain and valuable fact to be learned from the halo. The halo has established the extreme rarity of radioactivity as an atomic phenomenon. One and all of the speculations as to the slow breakdown of the commoner elements may be dismissed. The halo shows that the mica of the rocks is radioactively sensitive. The fundamental criterion of radioactive change is the expulsion of the alpha ray. The molecular system of the mica and of many other minerals is unstable in presence of these rays, just as a photographic plate is unstable in presence of light. Moreover, the mineral integrates the radioactive effects in the same way as a photographic salt integrates the effects of light. In both cases the feeblest activities become ultimately apparent to our inspection. We have seen that one ray in each year since the Devonian period will build the fully formed halo, unlike any other appearance in the rocks. And we have been able to allocate all the halos so far investigated to one or the other of the known radioactive families. We are evidently justified in the belief that had other elements been radioactive we must either find characteristic halos produced by them, or else find a complete darkening of the mica. The feeblest alpha rays emitted by the relatively enormous quantities of the prevailing elements, acting over the whole duration of geological time, and it must be remembered that the halos we have been studying are comparatively young, must have registered their effects on the very sensitive minerals.

And thus we are safe in concluding that the common elements, and, indeed, many which would be called rare, are possessed of a degree of stability which has preserved them unchanged since the beginning of geological time. Each unaffected flake of mica is thus unassailable proof of a fact which, but for the halo, would probably, have been for ever beyond our cognizance.

Cost of Ice Making in Small Plants*

By R. P. Kehoe

The business of ice manufacture is sometimes disparaged and manufacturers of such machinery are criticized for the apparent failure of a few plants. The cause is usually attributed to inefficient equipment or misleading statements on the part of the builders. Occasionally the purchaser is convinced that the plant is properly constructed, but believes his operators to be at fault.

In almost every instance the lack of success arises from local conditions which the most perfect plant could not overcome. This is especially true in installations of small capacity. Large plants are only installed where there is considerable demand which lasts for several months during each year, but small plants may be installed in localities having little population and requiring ice for only a comparatively short period.

In cities of any size there is a certain demand throughout the year. Hotels, saloons, butchers and the like require ice even in the coldest weather. Inhabitants of cities are also accustomed to use ice constantly. But in suburbs, country towns and villages little or no ice is used during the cooler months. June, July, August and September are practically the only months which can be counted on to produce a maximum demand. Moreover, some days during these months will be cool and the business will fall off. Under such conditions the entire output of a plant may not exceed 30 to 40 per cent of the full yearly capacity.

If the percentage of yearly output were precisely the same for two plants, one of large and one of small capacity, the manufacturing cost per ton should be and is less in the large plant; but usually the small plant must bear the burden of a low yearly load factor, so that it is actually necessary to make a more careful investigation of local conditions governing demand and selling price in the building of a small plant than a large one.

The daily manufacturing cost when the plant is operating at full capacity gives positively no idea of possible success; such figures are entirely misleading. Many small plants now in operation show little or no profit at the end of each year and the owner cannot understand it when the daily operating cost per ton is only about half the selling price. The cost of upkeep, depreciation and labor during shutdowns and comparatively low yearly consumption are not considered.

Very often in a small business the cost of delivery and manufacturing are confused, and the fact that a loss in one end eats up part or all of the profit in the other may never be discovered. The average owner of a small ice plant is not often an expert business man and cannot analyze the combination of manufacturing and delivery of ice with much accuracy.

The accompanying tabulation clearly shows how much the yearly consumption will affect the total cost of production. The figures covering labor and fuel represent an average and can be adjusted to suit any special locality, but the comparison is a true one in any case.

* Reproduced from *Pure Products*.

In the table figures are given for total yearly production equivalent to three, four, five and six months' full capacity. It must be understood that no plant will simply operate for these periods during the year and then shut down. Maximum capacity is usually required throughout July and August and possibly part of June and September, but the balance of the time will only demand from 50 per cent down to a very small percentage of the full output. The total amount, however, will in almost every instance equal the full capacity for from three to six months. A plant operating with a yearly load factor of 25 per cent or the equivalent of three months' production may be taken as a bad case, although this is entirely possible in certain localities, particularly in the Northern States or where ice is only required for a summer population. The equivalent of six months' production would, on the other hand, represent good conditions for an average plant.

The estimated costs of installation are fairly liberal, but can be depended upon to be very nearly correct. The building for the 5-ton plant is assumed to be of very cheap construction on account of the small size of the plant. The larger plants would need stronger and more elaborate structures, which explains why these figures are not exactly proportional.

In the 5-ton plant the engineers can fire the boiler and also pull the ice. For the 10-ton plant one tankman is figured on to harvest all the ice during the day, as the operation can be arranged in this manner by providing a distilled water-storage tank to collect the condensate during the night. Four men are necessary for both the 15- and 20-ton plants.

During the cooler months the labor expense can be reduced somewhat, and in the tabulation this item is calculated at 50 per cent of the full expense, which can be assumed as a fair basis. On the mechanical equipment 5 per cent depreciation is conservative, because it does not cover any repairs or upkeep. If this 5 per cent is actually set aside as a sinking fund and invested to earn a normal rate of interest it would equal the total value of the equipment in about 15 years. In addition, 5 per cent on the entire investment is calculated for yearly repairs and incidentals.

The cost of property has not been considered and would depend upon the location. This part of the investment really need not be required to earn anything, as generally it will increase in value during the life of a plant. It can therefore be considered apart.

The last two lines are of particular interest. It may be noted that the total cost per ton of ice per year ranges from $2.09 in the 20-ton plant with a 50 per cent load factor to $4.62 in the 5-ton plant with a 25 per cent load factor. Furthermore, the selling price necessary to obtain to earn 10 per cent on the investment ranges from $2.69 to $6.29 per ton. These figures may be astonishing to those who only figure on the regular operating expense without regard to the other items, but they are nevertheless perfectly true and represent the only proper basis on which to figure profits.

This article is not intended to discourage investors, for there are hundreds of very profitable plants now in operation that indicate the success of the business in general. The gradual decline of the natural ice trade occasioned by the condemning of questionable sources of supply and the growing preference for the purer artificial product promises a still better outlook in the future. A few failures, however, are often considered to the disadvantage of the entire business and a more universal knowledge of the true circumstances should help the situation.

Cost of Ice per ton in Different Sized Plants and at Different Load Factors

Capacity, tons ice per day of 24 hr.	5				10				15				20			
Total period of full operation, months	3	4	5	6	3	4	5	6	3	4	5	6	3	4	5	6
Yearly load factor, per cent	25	33	42	50	25	33	42	50	25	33	42	50	25	33	42	50
Investment																
Mechanical equipment complete	$6000				$8500				$12,000				$15,000			
Building	1500				3500				5,000				6,500			
Total investment (excluding land)	$7500				$12,000				$17,000				$21,500			
Daily Operating Expense																
One day engineer	$2.50				$3.00				$3.00				$3.50			
One night engineer	2.00				2.50				2.50				2.50			
One day tankman	.....				2.00				2.00				2.00			
One night tankman	.....				.....				2.00				2.00			
Coal @ $3.50 per ton	3.50				7.00				10.00				13.00			
Ammonia, oil, waste and supplies	0.50				1.50				2.25				3.00			
Net operating expense per day	8.50				16.00				21.75				26.00			
Net operating expense per day per ton ice	$1.70				$1.60				$1.45				$1.30			
Total Cost of Operation per Year																
Daily Operating Expense during period of full operation, dollars	765	1020	1275	1530	1440	1920	2400	2880	1958	2610	3263	3916	2340	3120	3900	4680
Half of labor expense for balance of year	608	540	473	405	1013	900	788	675	1283	1140	998	855	1350	1200	1050	900
Fixed Charges: 5% depreciation on cost of mechanical equipment	300	300	300	300	425	425	425	425	600	600	600	600	750	750	750	750
Fixed Charges: 2% depreciation on cost of building	30	30	30	30	70	70	70	70	100	100	100	100	130	130	130	130
Fixed Charges: 5% on total investment for repairs, taxes, water and incidentals	375	375	375	375	600	600	600	600	850	850	850	850	1075	1075	1075	1075
Total annual expense, dollars	2078	2265	2453	2640	3548	3915	4283	4650	4791	5300	5811	6321	5645	6275	6905	7535
Number of tons of ice produced annually	450	600	750	900	900	1200	1500	1800	1350	1800	2250	2700	1800	2400	3000	3600
Total cost per ton ice per annum	4.62	3.78	3.27	2.93	3.94	3.26	2.86	2.59	3.55	2.94	2.58	2.34	3.14	2.61	2.30	2.09
Minimum average selling price to earn 10% on investment	6.29	5.03	4.27	3.76	5.27	4.26	3.66	3.26	4.81	3.88	3.33	2.97	4.34	3.50	3.02	2.69

Fig. 1.—Charging Pintsch Buoy With Gas.

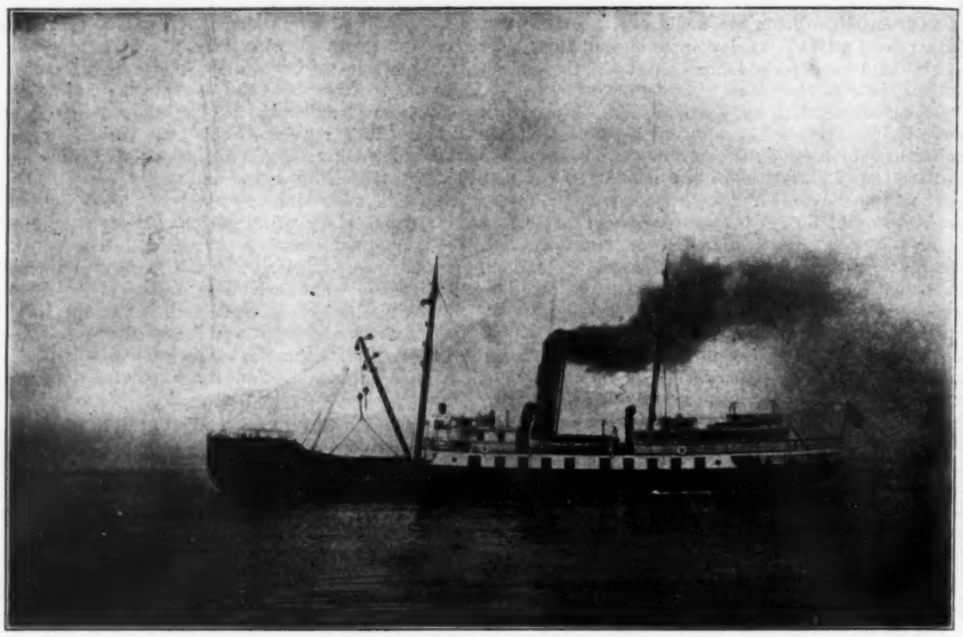


Fig. 2.—Lighthouse Tender "Tulip."

Lighthouses and Buoys of New York Harbor*

Safeguards for the Mariner

WITH the opening of Ambrose channel, the subject of lighthouse illumination of New York harbor has received most careful attention. Less than a decade ago the ocean entrance from the lower to the upper bay was crooked and narrow and beset with treacherous shoals through which only the most skillful and experienced pilots could navigate with safety. Ocean traffic to this port was steadily growing, and each year witnessed vast increases in the size and speed of vessels, with no apparent limitation in sight. Formerly the only sources of light for lighthouses were oil and oil gas, the former burned in a wick, the latter with a flat flame; both were feeble and of very limited range. But to-day conditions are different. The great liner making the port of New York at night is now guided by the powerful rays of the electric arc, the acetylene flame, and the incandescent light of Pintsch gas, and petroleum vapor. A broad, straight and deep channel now pierces the shoals of the lower bay, through which the ocean greyhound may pass with unabated speed to the safety of the upper bay.

MODERN AIDS TO NAVIGATION.

The aids to navigation in New York Bay, which will be briefly described, comprise lighthouses whose source of illumination is electricity or oil vapor; beacons; combined lighted acetylene and warning buoys; combined lighted Pintsch gas and warning buoys; automatic whistling and bell buoys; conical and tubular buoys of large size; spar buoys and can and nun buoys of various sizes. Other aids are lightships, submarine warning stations and wireless telegraph stations.

LIGHT SIGNALS.

The lighted aids have distinctive characteristics, viz., fixed lights, revolving lights and flashing lights. The single fixed light as established at Sandy Hook light station and Conovar beacon light station, consists of an oil vapor light within a fixed or stationary drum lens. (For fixed range lights a bull's eye or holophoto is used.)

The revolving lights, such as Navesink light station and Nomer Shoal light station, are employed only for large lights of the first, second, third and fourth orders, and are equipped with lenses sometimes of the most wonderful and complicated construction, to produce flashes of different durations and intensities. The lens is supported on a table or float, which is revolved around the light in a bath of mercury by means of a falling weight or spring clock.

The flashing light is used on buoys and beacons and is produced by the pressure of the illuminating gas (acetylene or Pintsch gas) upon a flexible bellows or diaphragm, which operates a valve or valves controlling the flow of gas to the burner. A tiny pilot burner maintains a light at all times and intermittently lights the main flame as gas escapes with each impulse of the diaphragm. Thus light and dark intervals are produced.

Fixed drum lenses are also used with this system and vary in diameter from 8 to 15 inches. Unaided, the naked light would not carry far, and its beams would be diffused and scattered in all directions. Therefore, one of the subjects which received the earliest attention was the means for collecting and concentrating the light rays and projecting them in a horizontal plane. For this purpose two systems were developed, the first being the Caloptric or reflector system, now almost obsolete, the second the Droptic or lens system, used to-day in all modern lighthouses and buoys. In passing, it may be of interest to note that all cut-glass lenses used in the lighthouses and buoys of the United States are made in Germany, France or England, and that all attempts (and many have been made) to manufacture them in this country have failed.

INCREASE IN LIGHT POWER.

The increases in intensity of light due to the use of new illuminants are very high. For example, by substituting an oil-vapor burner for a circular wick burner of the same diameter the power of an apparatus is increased about three and one half times. The increase in power of the electric arc over the circular wick burner is still greater, but the use of electricity is still attended with too many disadvantages to permit its general extension to lighthouse illumination. The gain in lighting power of acetylene over oil gas (flat flame) is about 4 to 1, acetylene producing 45 candles per foot, oil gas 11. The gain in the lighting power of oil gas (Pintsch gas) burned in an incandescent mantle, over the flat flame, is also about 4 to 1. These increases in light power have all been effected within the last decade.

SOUND SIGNALS.

Of the sound signals used as aids to navigation in New York harbor, the most common types are the bell buoys and whistling buoys, both of which are frequently combined with light signals, e. g., the Ambrose channel entrance buoy is of the latter type (combination light and whistle).

The whistle on these buoys is sounded by the action of the waves on what is known as the Courtenay principle. A long tube descending from the buoy body has an area of about 7 square feet, and extends to the top of the body or flotation chamber. One or two smaller tubes connect from it to the whistle valve, which is provided with solid rubber balls, making a tight seat. The whistle, which varies from 8 inches to 12 inches in diameter, is fastened to the valve and protected by the superstructure which carries the lantern. As the buoy rises on a wave air is sucked in through the valve, and as the buoy descends is compressed and forced

* Reproduced from *International Marine Engineering.*

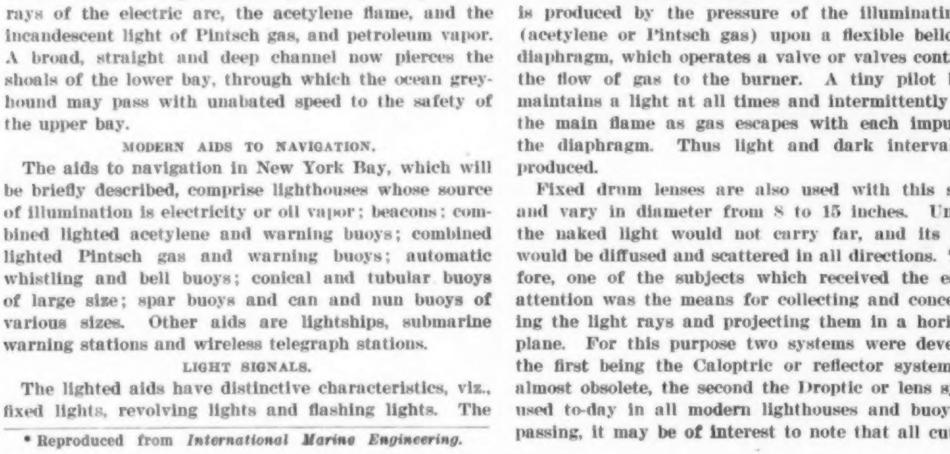


Fig. 3.—Sentinels of the Sea.

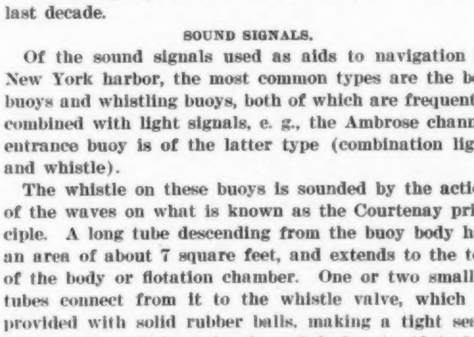


Fig. 4.—Picking up an Old Bell Buoy.

Fig. 5.—Hauling an Acetylene Gas Buoy Aboard Lighthouse Tender "Larkspur."

Fig. 6.—Lamp for A G A Buoy.

violently through the whistle, producing a loud moaning noise.

The bell buoys are familiar to everyone who sails down the bay. The trinity type with four hanging tappers is the most usual form. This type is illustrated in Fig. 4, where it is being taken in to be cleaned and painted.

The Ambrose channel light vessel is equipped with a 12-inch steam whistle, which sounds a blast every fifteen seconds in foggy weather. North Hook beacon and Old Orchard Shoal light stations are equipped with automatic compressed air sirens, while Nomer Shoal light station has a bell which is operated by machinery, striking once every thirty seconds. A similar bell signal is installed at Coney Island light station.

A TRIP DOWN THE HARBOR.

Having thus briefly described the various kinds of modern light and sound signal apparatus employed in New York harbor, the reader is invited in fancy for a trip on the lighthouse tender to the lightships, and returning up the Ambrose channel, will have each of the important light stations pointed out in the order they appear to the incoming navigator.

We embark at the General Lighthouse Depot, Tompkinsville, S. I., where the work of loading on supplies is proceeding. The powerful derrick of the tender picks up a ten-ton steel buoy from the dock and places it gently on the forward deck. Then follow two gas tanks, each weighing 1,500 pounds and containing a supply of acetylene sufficient to maintain the buoy lighted for six months or a year without interruption. The huge buoy lantern, weighing one fourth of a ton, is then swung aboard.

Soon we are under way, and reaching the station where the big A G A buoy is to be placed, the captain sings out his orders and the anchor plunges down to the music of chains rattling through the hawse pipe. The buoy is lifted from the deck and lowered into the water, where it is anchored to a cast iron sinker of hemispherical form or a square block of concrete containing iron punchings to give it additional weight, or perhaps an ordinary anchor, depending upon the nature of the bottom and the force of the currents. The buoy afloat, a couple of deck hands mount on it and remove the covers from the tank pockets, the tanks are lowered into place, and the gas piping coupled up, after which the covers are replaced. The lantern is then lifted onto the top of the framework, more than 16 feet above the water, and bolted down. The gas piping is coupled up and joints are tested for leaks with soap-suds. The valves are then opened and a match is applied to the burner. Soon the anchor is weighed and the tender

Fig. 7.—Cleaning and Adjusting Lamp on Gowanus Shoals Buoy.

gets under way again, heading for the upper Pintsch buoy at Gedney channel.

The pressure gage on this buoy indicates the need of a fresh charge of gas. The gas used on these buoys is made from crude oil at a station on shore, and is pumped into small steel containers or bottles to a pressure of 100 atmospheres, so that it is easily transported to the buoys. To charge the buoy a high-pressure hose is coupled between the tank and the buoy and the gas is allowed to flow in until it attains a pressure in the buoy of 12 atmospheres. This operation is being performed in the picture shown in Fig. 1.

The modern Pintsch gas buoy light employs a spherical incandescent mantle in which the gas is burned at 1 pound pressure, producing a light of 40 candles per foot, as compared with less than 12 candles with the old style of burner with naked flame. The average life of mantles on buoys taken from over 2,000 buoys is said to be three months. Fig. 8 illustrates a Pintsch mantle being renewed.

At length the Ambrose channel lightship is reached, and after transferring supplies we prepare for the return trip to the depot.

The Ambrose channel lightship is a straw-colored vessel with two masts and one funnel which also carries the steam fog whistle. It is equipped with wireless. On the foremast is carried a lantern containing an electric arc light, which shows a flashing light of 12 seconds duration, followed by eclipses of 3 seconds. This light is visible 13 miles. She carries a crew of about 15 men.

The next light visible is the great gas and whistling buoy at the intersection of the Gedney and Ambrose channels. This buoy is known as the Willson buoy, and employs acetylene as an illuminant. Its characteristic is 5 seconds light, followed by an eclipse of 5 seconds. The gas is generated from calcium carbide within the buoy itself. The generating chamber contains about 3,000 pounds of carbide at a charge, and as this carbide is capable of producing 4½ cubic feet of acetylene per pound, there is altogether available 13,500 cubic feet of gas, sufficient to keep the buoy lighted for a year or more. Calcium carbide is made by fusing together a mixture of coke and lime in an electric arc furnace. When broken up it resembles granite rock. Acetylene produces a light of great brilliancy,

Fig. 8.—Putting Mantle on Lamp of Pintsch Gas Buoy.

Fig. 9.—Collection of Buoys at Lighthouse Depot.

of such intensity as to be comparable only to sunlight.

Away on the port side is seen the quick, blinding flash of Navesink light station, an electric arc light with a first-order lens, producing a light of more than 1,000,000 candles, visible at 22 miles. This type of light station is termed a landfall light.

The range lights on Staten Island now come in view. These are high-power incandescent oil-vapor lights. The incandescent oil-vapor light is steadily replacing the oil lamp with circular wick. It gives a light of many times greater power with a smaller consumption of oil. Briefly, it consists of a small oil tank connected to a smaller air tank, in which air is compressed by a hand pump to a pressure of about 60 pounds per square inch. The oil is forced through a very fine tube to the vaporizer in the burner, where it is vaporized and burned in a mantle. The mantles vary from 1⅜ inches to 2⅛ inches in diameter, and from about 4 to 6 inches long. The light produced is dazzlingly white. Incandescent oil vapor burners are now used in all large modern lighthouses. The front range is equipped with a fog signal known as a Daboll trumpet.

We now enter the Ambrose channel, which is guarded at its entrance by an A G A combination light and whistling buoy. This buoy is on the port side and has a white light with the following characteristics: Two tenth second light, followed by four tenth second eclipse. As we pass the dismal howl of the whistle may be heard. As previously described, this type of buoy is provided with tanks containing dissolved acetylene.

These tanks or steel bottles are filled with an earthy porous mass of about 80 per cent porosity, which precludes the spreading of an explosion wave. This mass is saturated with acetone, a liquid hydrocarbon possessing the remarkable property of absorbing 25 times its own volume of acetylene for each atmosphere of pressure, so that a bottle 22 inches in diameter by 70 inches long contains at 10 atmospheres about 1,100 cubic feet of gas. This gas passes up into the lantern, where it is reduced in pressure to the fraction of a pound, after which it enters the flasher and the burner.

To the starboard we pass a Pintsch gas buoy with fixed red light; then alternately to port and starboard white and red buoy lights are passed, the red always on the starboard and the white on the port. Nun buoys (conical) are usually placed on the starboard side and can buoys (cylindrical) on the port.

Buoy after buoy is passed, and we soon leave behind lights on the inner range of Sandy Hook. Away to the port we passed Old Orchard Shoal light station with its light visible 13 miles. Its fog signal is operated by compressed air from a small compressor run by a gasoline (petrol) engine. It produces a prolonged blast of 7½ seconds duration, followed by a silent period of like interval.

Coney Island light, on the westerly end of the island, is now visible, its red light flashing at intervals of 5 seconds. It is visible about one sixth further, or over 16 miles.

Soon the clanging of Fort Wadsworth bell-buoy is carried to the ear, and then we observe the flashing alternately red and white light of Fort Wadsworth light station. Here, in foggy weather, a bell is struck by machinery; one stroke, then a silent period of 15 seconds. On the easterly side of the Narrows is Fort Lafayette fog signal station, also equipped with a bell.

Off St. George, Staten Island, at the easterly entrance of Kill von Kull, is Robbins Reef light station, which is kept by a woman. It has a flushing white light visible 13 miles, and a compressed air fog siren.

As we swing into the depot again we see behind Robbins Reef, faint against the glaring lights of Manhattan, the torch of Liberty illuminating the world. On this imaginary trip we have only seen a few of the lights of New York harbor, but enough to realize how carefully Uncle Sam safeguards at night the gateway to the Metropolis of the New World.

Progress in Power Production

A Forecast of the Direction of Future Developments

On this page we publish Mr. S. Z. Ferranti's James Watt lecture. An illuminating editorial which appeared in *Engineering*, relating to this lecture, forms a fitting complement, and is reproduced below.

Among other things Mr. Ferranti discussed the prospects of the internal-combustion engine and its rival, the steam-turbine. Mr. Ferranti has so often estimated accurately the probable trend of engineering progress that his views on this head are deserving of careful consideration.

He holds very definitely the view that the true field of the reciprocating engine is as applied to small developments of power, and that the attempt to adapt the Diesel engine for the propulsion of large high-speed ships is "against Nature." The larger a turbine is, the easier it is to build, and the greater the economy realizable. The converse is the case with the internal-combustion engine. A leading maker assures us that a gas-engine of 60 horse-power will give as good a figure for fuel consumption as one of 1,000 horse-power, but the latter is very much more difficult to construct and to operate with commercial success.

One eminent engineer, indeed, goes so far as to maintain that no engine on the Diesel system should be constructed to develop more than 200 horse-power per cylinder. It is, no doubt, true that a premature ignition in a Diesel engine of large size would have much the effect of an explosive shell; but whether the risk of this is real or imaginary can only be settled by prolonged practical experience.

The mechanical difficulties inherent in the application of the internal-combustion engine to really large developments of power are, on the other hand, unquestionably great; but Sir Trevor Dawson, in his address to the Junior Institution of Engineers, stated that it was now possible to build a battleship driven by internal-combustion engines, in which the total weight of fuel and machinery combined would be less than that of a steam-turbine plant.

Mr. Ferranti claims that in steam-turbine power-station practice a fuel consumption equivalent to 0.55 pound of oil per shaft horse-power is now feasible, and we may add that in a recent proposal submitted by responsible contractors a consumption of 10.5 pounds of steam per kilowatt-hour was guaranteed. The proposal, which was not accepted, involved the adoption of steam at an initial pressure of about 300 pounds per square inch, and a temperature of 815 deg. Fahr., with a vacuum of 28 inches. The unit proposed was rated at 5,000 kilowatts. Mr. Ferranti, in his address, gave some results obtained with a turbine of 5,000 shaft horse-power, working with the system of intermediate superheating with which his name is particularly associated. At two thirds full power 1 shaft horse-power was, he says, obtained for 7 pounds of steam, and he estimates that at full load this figure will be reduced to under 6 pounds. Taking a boiler and superheater efficiency of 82 per cent, he claims, as mentioned above, that this is equivalent to a consumption of 0.55 pound of oil-fuel per shaft horse-power. In this connection attention should, perhaps, be drawn to the experiments now in progress, which promise a higher efficiency for the boiler plant than the 82 per cent premised above.

In connection with the present rivalry between the steam-turbine and the internal-combustion engine, it has to be remembered that in actual practice it is no longer true that the higher the initial temperature in a heat engine the greater its fuel economy. Gas-engine builders have long known that compression carried beyond a certain limit, found by experience, led to a lowering of the efficiency of the engine. This may no doubt be due in part to mechanical causes, but thermodynamic considerations are also involved. With low temperatures the heat which passes into the cylinder walls is mainly transferred to them by conduction; but at high temperatures, though the loss by conduction is increased, it begins to be swamped by the loss due to the heat which is transferred to the walls by radiation. The rate of heat transfer by radiation is proportional to the fourth power of the absolute temperature, so that it is sixteen times as much at 2,000 deg. Cent. as it is at 863 deg. Cent. A limit is thus soon reached at which the loss by radiation far exceeds the gain theoretically due to the greater availability of the heat. It is this fact which makes it improbable that the efficiency of ordinary internal-combustion engines can ever be very materially improved. With steam plant, on the other hand, the present limits as to steam temperature are probably distinctly below what will prove quite practicable in the near future. In this connection it is of interest to observe that with such degrees of superheat as are now usual the gain in economy is substantially greater than is theoretically due from the ordinary theory. In turbine practice this may be in part due to wet steam being "supercooled" every time it expands through a series of guide-blades. The subsequent re-establishment of thermal equilibrium must involve a growth of entropy, and a corresponding loss of available energy. If this view be correct, and it is certainly true in part at least, the gain effected by superheating will become more and more nearly that theoretically due, as the temperature is raised, the limit being reached when the steam is discharged to the condenser in the dry saturated state. While further superheating beyond what is necessary for this may lead to increased economy, it appears probable that the rate of gain may be expected to be less than the theoretical, in place of in excess of the latter as is now the case with the usual limits of superheat.

Prime Movers*

Our Debt to James Watt

By S. Z. Ferranti

The work of James Watt, and the various mechanical contrivances which he invented, and their effect upon the world's progress are familiar subjects. It is less well known what these achievements cost James Watt, and of the enormous difficulties he had to overcome in order to bring about the utilization of his inventions. It is well that we should stop and consider this side of the question. Those of you who have read his life will remember what a continual struggle it was to try to develop the invention after he had conceived the first great fundamental ideas which constituted it. It was exceedingly difficult to get anyone to take up the idea and to get together the necessary funds for trying the experiments. People either had not the money or had not the faith to find the money to help him. When at last he got some measure of assistance there were endless mechanical difficulties to overcome, as in those days engineering practice was of the crudest possible nature. In fact, with our present knowledge and facilities for the production of engineering work it is hard to conceive what the position was in his day, and how impossible it was to satisfactorily make the most ordinary engineering contrivance.

I consider that one of the greatest things ever achieved by James Watt was his discovery of Matthew Boulton, for unless Watt had been fortunate in this, and also, after a weary delay in persuading Boulton to join with him in working out the invention to a successful issue, it is hard to say whether or not he would have lived to see its successful application. The most distressing part about the whole business of Boulton's and Watt's struggle in the development of the steam engine was the fact that for years they lived on the verge of bankruptcy. Even twenty years after making the invention, during which time they had labored incessantly and put in all the money that Matthew Boulton could find, no return was being obtained upon the investment. We have records in the letters which passed between the two partners of Watt's continually recurring despondency in relation to the business, and if it had not been for the magnificent support extended to him by Matthew Boulton I cannot conceive how his inventions could have resulted in anything but failure and complete despair. We are all here to honor the name of James Watt, but I think we can hardly do this without at the same time honoring that magnificent man, Matthew Boulton, who had so large a share in the success of Watt's endeavors.

Although the above things happened a great many years ago, no doubt very similar cases have been continually recurring. In fact, I am sure that the same sort of thing is going on to-day in many directions. I am also afraid that in this country the difficulties of inventors are very great owing to the want of interest in anything new. Although I think we have plenty of inventors, we have very few Matthew Boultons, and from the point of view of progress and development of the country it is men such as he who are wanted to-day. It is generally believed that the immense development which has taken place in Germany is largely due to the intelligent use of her scientific men by the commercial community; in fact, there is a saying that the prosperity of modern Germany is built up on the work of her professors. In the United States there also appears to be a much better chance for the man who is desirous of developing new things, and this undoubtedly must help these countries to progress and keep ahead in the industrial struggle. Nowadays the working out of new ideas and the perfecting of existing processes is very different from what it was in the time of James Watt, and I think that to-day it is probably far more costly to make any great advance than it was in those days. It is, therefore, necessary in the development of any new idea to get together a very considerable amount of money to do the experimental and pioneer work, and as the return upon such things is so uncertain

* Read at the James Watt Club, Greenock, Scotland, January 16th, 1913, and published in *The Engineer*.

is hard to find the necessary support. Still, it is vital to the progress of the country, and in order that we should not fall behind our competitors that great risks should be taken in the development of new ideas, and it would be a good thing for the country generally if there were more keenness in this direction. I do not think that to-day this country is spending anything like enough in the development of new ideas. Expenditure on development work must be looked upon as money spent on insurance, which is made to provide for our business in the future, in order to keep abreast of Germany and the United States, our principal competitors. There are, of course, some notable exceptions, and to these people and companies all honor is due.

James Watt, besides inventing and developing the modern steam engine, had turned his attention to the question of applying steam to motive purposes on what he called a steam wheel, so getting direct rotary motion. The work of Sir Charles Parsons in the invention and development of the rotary principle to the production of motive power by means of steam must ever be remembered as a great advance in the development of prime movers. The turbine, notwithstanding its very low efficiency as first constructed, was gradually improved until high mechanical efficiencies of conversion have been reached. Especially is the turbine valuable in the production of large powers, and in taking advantage of high degrees of vacuum. Before, however, the modern turbine had been developed, another idea had been pursued with a view of simplifying the process of power generation, and at the same time getting a higher economy.

The lecturer then briefly outlined the development of the internal combustion engine, commenting particularly on its high negative work.

He then continued:

If the engines of high negative work had been invented in the days of James Watt, they could never have been made workable, as the materials available at the time would not have stood the temperature, and mechanical knowledge and construction was not sufficiently advanced to enable that high degree of mechanical efficiency to be reached which is necessary with engines of this class. The development of the internal combustion engine of high negative work, which was started before the birth of the modern steam turbine, has been vigorously pushed on over a period of years concurrently with the work done on the turbine, and now both are competing for premier place in furnishing the world's power. The turbine, though less economical in actual fuel consumption, has many great advantages, and for large powers is to-day practically unassailable. For small powers the turbine is, naturally, uneconomical. From a careful and dispassionate consideration of the subject it seems, according to present knowledge, to be clear that for small powers the internal combustion reciprocating engine is in every way the best. At the other end of the scale the turbine is the only means of filling our requirements to-day. Between these two extremes there is a doubtful dividing line, where either form of engine may best serve the purpose according to the conditions of the particular case.

As the turbine gets bigger, so is it easier to construct, and it also becomes more economical. As the gas or oil engine gets bigger, I need hardly remind you how the natural difficulties increase. On the other hand, as the turbine is reduced in power its economy falls off badly, and it is difficult to make a satisfactory design. The internal combustion engine, on the contrary, becomes a most satisfactory and economical machine in small sizes, as witness the thousands of gas engines in use all over the world, and the beautiful engines working on the Diesel cycle, which are small enough to avoid water-cooling of the pistons. I think that this division of the means of power production by large and small units between the rotary and reciprocating machine, is almost a natural law, and those who seek to evade it must either invent some new principle or court endless trouble, expense, and failure. To-day, with a complete disregard of the above principles, the advocates of the Diesel engine for marine propulsion are spending vast sums of money on its development, but even this usually all-powerful force may not prove enough to make a wrong principle right. The daily press, and also our well-informed technical journals, tell us of all the wonderful successes of large oil engines in Germany, and elsewhere, but I can assure you that few people have any conception of the failures and breakdowns which have occurred, and which are repeatedly occurring with the big experimental engines that have been constructed. In Germany especially, where so much has been done in this direction, they carefully avoid informing the foreigner on these points.

The subject of prime movers is one in which I have always been most interested, and in following it my constant aim has been to increase the amount of work that can be usefully obtained from a given amount of fuel. It is, of course, well known that the higher the temperature of the working fluid the higher is the economy that can be obtained. High temperatures have, however, proved very difficult to work with, and as an instance of this the low-working temperatures of turbines for marine propulsion may be pointed out. Seeing, however, that the difficulties were mechanical, and that great advantage could be derived if these troubles were overcome, I commenced experimenting some years ago, and have now, after many failures, and the expenditure of much money and time, produced a turbine which at the highest temperatures and with great and rapid variations of temperature is quite free from mechanical troubles. Indeed, I believe that this turbine is, perhaps, the strongest from a mechanical point of view that has yet been produced. Moreover, contrary to what might have been expected with a high temperature machine, it runs with certainty with a blade end clearance that is so small that it is almost negligible from the point of view of leakage loss, and the fear of the possibility of stripping appears to have been effectively removed. In this turbine I superheat the steam initially, and after the first expansion, and while it is still superheated, re-superheat it before it does its work in the second stage of the turbine. After this it is exhausted in a superheated condition through a regenerator to the condensor. The whole of the blading is electrically welded so as to avoid the straining due to caulking at the high temperatures that are reached, and also the loosening that occurs owing to the same cause. The blading is formed of mild steel, with a thin coating of pure sheet nickel electrically welded on to the surface. The blading is most accurately finished to shape by a process of step-by-step pressing under very heavy pressure. The blading, the sections of which are very exact, are welded in position with the accuracy of the automatic machine that is used for the purpose, and every opportunity is thus given for realizing the best results. Although the turbine is of the reaction type no balance dummy is used. The whole of the end load is taken on a specially constructed thrust, thus saving steam leakage. The steam is worked as a gas at high temperature throughout the turbine, and this, coupled with the many improvements above referred to, has given very good results.

The 5,000 horse-power machine, which has now been running for some time, when tested at a load of two thirds full power, has given a shaft horse-power on 7 pounds of steam, which, if supplied by an oil-fired boiler superheater system of 85 per cent efficiency, which has already been exceeded in central station practice, would consume less than 0.625 pound of oil per shaft horse-power. From many tests already made it appears that when this turbine is run at full load under favorable conditions, it will take less than 6 pounds of steam per shaft horse-power, and that the system under the conditions named will have a thermal efficiency of over 24 per cent, corresponding to an oil consumption of about 0.55 pound of oil per shaft horse-power. The tests are being proceeded with, but as the turbine is run continuously in supplying power to a large works with a constantly varying load, it is not easy to do what is necessary to enable tests to be carried out. So far as I can see, this system, when applied on a large scale, will be capable of giving an overall thermal efficiency of 29 per cent. When the advantages of the turbine system in the way of lightness, simplicity, and certainty are borne in mind, and when they are compared with what is known of the complicated reciprocating oil engines now being introduced for marine purposes, the possibilities of the new system of high-temperature gas-steam turbine become of great interest.

Steam as a practical motive power, so brilliantly invented and applied by James Watt, has had a long and most useful application in our civilization, but it cannot be looked upon as the eventual solution of the power problem even for large powers. It can, however, be immensely improved in efficiency, and as it does not appear that there is any other system at present which will fill the same requirements, it is probable that it will still have an enormous application. With a high-temperature steam turbine of large size generating electricity to supply power for all purposes on land, one has the advantage of a machine of the highest efficiency which is not limited to oil for its fuel. It is probable that as improvements are made the whole of the coal used for firing these large units will be gasified and the by-products recovered. When this result is brought about we shall have not only an ample and cheap supply of fertilizer for the land, but also a great quantity of the tar oils which will form a suitable means of firing for naval purposes, and will relieve us from the necessity of purchasing fuel oil abroad and the risk and cost which this process involves. We will also have an ample supply of benzol for all our small moto requirements. This, I think, is the solution of the fuel problem for these motors rather than in the production of alcohol on a large scale from the land, as has lately been advocated. When we are supplied with ample quantities of fertilizer at a low cost, both the land and the labor involved for the production of alcohol will be much better occupied in other ways. After all, the great problem for this country is to so utilize the coal that we produce that we make it fill our every requirement. This, as I have shown you, will be done in the not distant future.

The electric motor, which gives its power in a rotary form, and which is supplied from very large power stations, is displacing all forms of small engine. It is, therefore, probable that in the future small prime movers will only be required to propel cars and boats, and that all stationary motors will be electric. The electric motor, with its one running part, so easily and conveniently applied to all purposes is a good illustration of the desirability and even the necessity of the rotary principle of the engine. Reciprocating forms of engine will no doubt be used for a long time, but they can only be regarded as makeshifts, and so soon as an equally efficient machine for any particular purpose is developed it must surely displace the reciprocating motor. No doubt, as knowledge increases, many forms of prime mover will be developed of higher and higher economy. It is difficult to predict the form of the prime mover of the future, but in search of the highest economy, and with the limitations of temperature imposed by known materials, one is inclined to look to electricity converting the energy of the fuel at low temperatures, and giving its power in rotary form as the most likely eventual solution.

Unmounting and Remounting Photographs

One of the most disagreeable jobs which have to be tackled by the photographer is the unmounting of a number of photographs, either for the purpose of remounting them in uniform style or inserting them in an album. It must be borne in mind that few printed-out prints, either on gelatine or collodion, will stand damping for any length of time, some apparently fresh prints showing signs of fading in a very few hours. It is, therefore, very desirable, if a trial print or two be found reluctant to move, that an effort be made to unmount the prints in their dry condition, and this is not so difficult as it would appear. We were watching a workman engaged in doing this recently, and give his method for the benefit of our readers. It was based upon the curious fact, doubtless known to some, that when separating two pieces of paper which have been pasted together, one can always be prevented from tearing by keeping it flat and bending the other away from it. This can easily be proved by trying to remove a postage-stamp from an envelope. If it be well stuck, and you attempt to pull the stamp off the envelope, the former will tear, in nine cases out of ten; but if you turn the stamped side downward upon a smooth table, and, holding one corner of the stamp, pull the envelope upward, bending it back at the same time, the stamp will come away perfectly, usually with a thin film of the envelope paper adhering to it. By applying this method to a mounted photograph, it will be found easy to strip the print with very little risk of injury. The mount must first be split, and as many layers as possible removed, so that the remainder is sufficiently flexible to permit of the necessary bending. It will be found that as a rule, the back of the print will be covered with a thin, even coating from the face of the mount. This, if quite even, should be allowed to remain; but if any portions of the board adhere, they should be rubbed down with fine sandpaper to the thickness of the rest.

Prints which have been dry-mounted may be taken off by heat in the usual way; or, if the photographer does not possess a press, they may be well warmed in front of a stove, and the stripping effected by ironing with an ordinary flat-iron, and raising the print as the iron is passed to and fro. If Morgan's dry-mounting solution has been used instead of adhesive tissue, it is better to strip by the method already described.

For remounting, a strong adhesive is necessary, as the prints are more or less stubborn in their nature, and they cannot be damped, as this would disturb the finishing. A good dextrine mountant may be used; but glue is better, this being applied by the bookbinder's plan of coating a warm slab of glass or marble with the glue, and laying the print face upward upon it. When it has picked up the glue, it is removed, placed in position on the mount, and well rubbed down. The job which we saw in progress consisted of about six dozen prints, varying in size from 15 inches by 12 inches to cabinet, almost every process being represented. Many were highly worked up, and some fully colored; yet all these were successfully removed from their mounts and transferred to an album. This mode of working is, of course, based on the once well-known method of splitting a print to remove printing from the back, which was also employed by some of the old calotype workers when they got stains on the back of their paper negatives. It consists of pasting the print between two layers of very tough paper, and, when just dry, starting one corner with a penknife, so that on pulling the two outer sheets apart the print is divided, half adhering to one sheet and half to the other.—*British Journal of Photography.*

The Aerator—A Gigantic Fountain in Which New York's Entire Water Supply Can be Sprayed Fifteen Feet High.

Notes on New York City's Water Supply System

Some Features of Interest At and About Kensico Reservoir

In this week's issue of the Scientific American a general account has been given of the great water supply system for New York city now in the course of construction. The extreme limit of this system lies over 120 miles from City Hall, and is not very readily accessible to the traveler. Much interesting work is going on near White Plains, at the Kensico reservoir, within easy reach from New York city, and it is proposed to give here some account of certain features of this part of the enterprise not dealt with in detail in the Scientific American.

KENSICO RESERVOIR.

Kensico reservoir will receive but a negligible quantity of water by drainage, its chief function being to serve as an equalizing basin fed from the reservoirs collecting the drainage from the water-sheds in the Catskill region. It is situated east of the Hudson, and 30 miles from the City Hall, and will contain several months' supply of Catskill water. It will act as an emergency storage reservoir, so that the supply will not be interrupted in case of inspection, cleaning or accident to the 77 miles of aqueduct between it and Ashokan reservoir. It is now being constructed under contracts amounting to nearly $8,500,000. It is on the line of the Catskill aqueduct and will be, in a more distant future, the great wholesale distributing reservoir for the metropolitan district.

This reservoir will be formed by the Kensico dam across the valley of the Bronx River, about three miles north of White Plains and fourteen miles north of Hill View reservoir. Its normal flow line will be at an elevation of 355 feet above mean sea level, and will cover 2,218 acres. Its total capacity will be about forty billion gallons, and the available capacity will be twenty-nine billion gallons, or about 60 days' continuous supply at 500 million gallons daily, the present total consumption of Greater New York. The maximum depth of water behind the dam will be 155 feet. The water will be about 110 feet deep over the surface of the old Kensico reservoir, which was developed by the Department of Water Supply, Gas and Electricity in 1885, and will be 54 feet deep over the surface of the Rye ponds.

The Catskill water will be delivered into the Kensico reservoir at the upper end of the Bronx valley where the normal surface of the reservoir, elevation 355, is at the hydraulic grade line of the Catskill aqueduct. The water will be drawn from the reservoir through a short tunnel at a point on the west side of the reservoir about one mile above the Kensico dam.

At the reservoir end of this tunnel is the upper effluent gate-house containing sluice gates for controlling the flow from the reservoir into the aqueduct. At the lower end of the outlet tunnel is a large gate-chamber in which the flow of the water will be regulated by valves and either diverted through the Kensico aerator or sent directly to the aqueduct. Near the lower gate-house is the screen chamber in which all the water will be passed through fine mesh screens before it flows on toward Hill View reservoir. A reinforced concrete bypass conduit 11 feet in diameter and 11,000 feet long, from the inlet gate-house at the upper end of the reservoir, connects with the upper effluent gate-house so that water may be delivered directly to New York before the completion of the Kensico reservoir.

THE AERATOR.

The function of the aerator is to effect a preliminary purification of the water, by projecting it in a number of jets into the air, so as to expose a large surface to the oxidizing action of the atmospheric oxygen. The aerator may be operated in conjunction with filters located at Eastview, or its action alone may be relied upon. The whole or part of the water flowing through the aqueduct system may be aerated when the reservoir is full. The immense fountain formed by the aerator—with its sixteen hundred nozzles spouting jets to a height of 15 feet—will form an imposing sight, and the landscape architect has spent pains laying out the surrounding park to make a fitting setting for this the world's greatest fountain.

The aerator basin is a shallow concrete-lined pool (see the accompanying headpiece) 460 feet long and 240 feet broad at its widest part. From the pool the water is collected through a slot running along the axial line and is thence delivered to the aqueduct.

The nozzles are so designed as to spread the water into fan-shaped jets having a whirling motion. The jets are arranged in lines and spaced about 16 inches apart, so that the adjacent fans will meet very near the orifice, forming a solid wall of spray. The lines of nozzles are arranged in patterns designed to please the eye and to produce an artistic effect.

THE KENSICO BYPASS AQUEDUCT.

In order to make Catskill water available before the completion of the Kensico dam, a bypass aqueduct has been laid, connecting the future inlet and outlet of the reservoir. While this bypass is primarily intended as a temporary structure, it will remain available for use if at any time for one reason or another it is desired to deliver water directly from the Ashokan reservoir to New York. The total fall from inlet to outlet of the bypass is 32 feet, distributed over a length of 2½ miles, an average gradient of 0.0024, giving a velocity of 10 feet per second through the aqueduct.

When the reservoir is full the bypass will be completely submerged, and the masonry is so designed that when the aqueduct is empty, its weight will be sufficient to overcome its buoyancy.

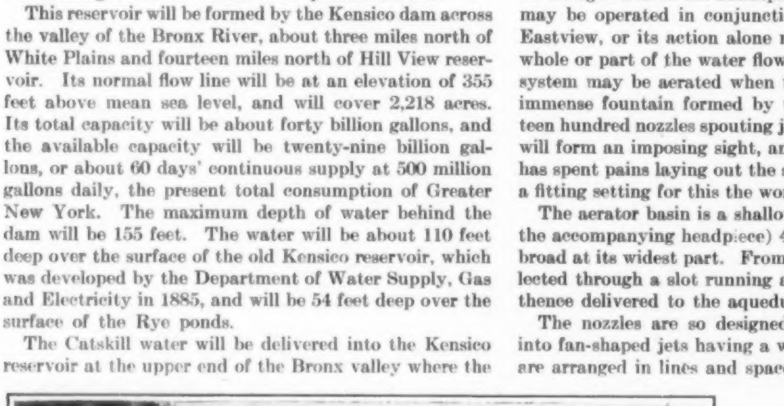
THE CROTON BLOW-OFF.

One of our illustrations gives a view of a feature of peculiar interest—a "blow-off" through which water may be discharged, when desired, from the aqueduct to the Croton reservoir. This is a giant outlet, capable of discharging a thousand million gallons per day, the stream being projected some 130 feet beyond the spreader. The slope is about 35 per cent, which will give the water a velocity of over 50 miles per hour.

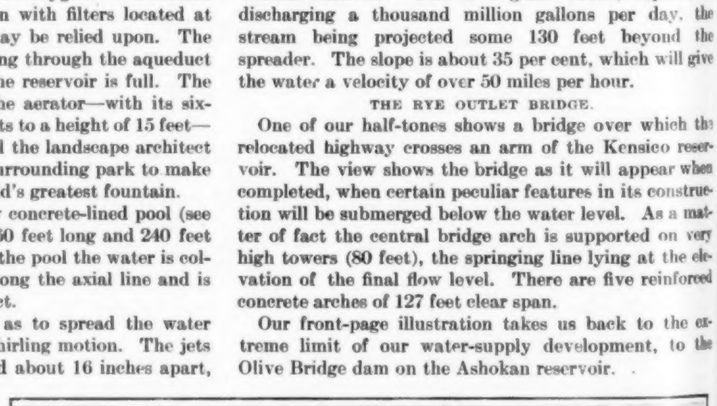
THE RYE OUTLET BRIDGE.

One of our half-tones shows a bridge over which the relocated highway crosses an arm of the Kensico reservoir. The view shows the bridge as it will appear when completed, when certain peculiar features in its construction will be submerged below the water level. As a matter of fact the central bridge arch is supported on very high towers (80 feet), the springing line lying at the elevation of the final flow level. There are five reinforced concrete arches of 127 feet clear span.

Our front-page illustration takes us back to the extreme limit of our water-supply development, to the Olive Bridge dam on the Ashokan reservoir.



The Croton Blow-off, Capable of Discharging Water at 50 Miles per hour.



The Rye Outlet Bridge, Whose Center Span is Based on Eighty-foot Towers.

Modern Pumps for High Vacua*

The Lowest Pressure Ever Attained

By E. N. da C. Andrade

THE widespread researches on the phenomena in electrical discharge tubes, which form so important a feature of modern physics, directed much attention to the question of obtaining high vacua. In 1888, as Lenard tells us,[1] an efficient vacuum pump was by no means an essential part of the equipment of a physical laboratory: at the present time it emphatically is so. In the following a brief account will be given of the modern forms of the different types of pumps, especial reference being made, however, to a pump recently invented by Dr. Gaede, as it depends on a principle never before applied, and seems from present information more efficient than any of its predecessors.

All vacuum pumps except this latest one of Gaede's make use of the principle employed by Otto von Guericke in the first air-pump—that is, the intermittent separation and discharge of a fraction of the gas from the reservoir to be exhausted by means of a piston, which in the mercury pumps takes a liquid form. We can, in reviewing the modern forms, divide these pumps into three classes: the solid piston pump, the hand mercury pump, and the automatic mercury pump.

The solid piston pump has preserved much of its original arrangement of valves, but has been modified in the Geryk pump, which may be taken as a modern example, by the use of layers of a particular oil in the place of packing. The valves are always covered by the oil, which takes up all clearance, and hence leakage is largely avoided, but the vapor pressure of the oil, though very small, prevents the highest vacuum being produced; however, 0.0002 millimeter of mercury can be attained. In a still more recent pattern, the "Rose" pump manufactured by Messrs. Cosser, there is no piston rod, the piston being of iron and moved by electromagnets oscillating outside the pump cylinder.

The forms of hand mercury pump now used are all modifications of the well-known Toepler pump. One of the simplest and most successful is that devised by Antropoff, in which the usual bulb is replaced by one of cylindrical form arranged obliquely instead of vertically.

The desire to reduce the time and labor attaching to the hand pump has led to the construction of a large number of mercury pumps which can be operated mechanically; in experiments such as those of Prof. Wien on canal rays such a continuously running pump is a necessity. The most convenient of these are the various rotary pumps, of which the first was devised by Schulze-Berge, and of which Kaufmann in 1905 brought out a pattern which has been considerably used. The essential of this is an inclined spiral tube which rotates continuously; a thread of mercury running in it cuts off and forces out a fraction of the air at every rotation. There are two such tubes; the pump, though efficient, is somewhat fragile and complicated.

The rotary mercury pump most in use at the present time is that of Dr. Gaede. It consists of an outer closed drum half filled with mercury, in which a second drum rotates. This drum is divided into chambers, which in turn become connected to the vessel to be exhausted; by the rotation they are filled alternately with gas and mercury, the gas being displaced into the outer space between the two drums and cut off from return by the mercury. The system is similar to the gas meter, only in this the moving gas effects the rotation, while in the Gaede pump the rotation sets the gas in motion. With this pump the pressure must first be reduced to a few millimeters of mercury by any rough preliminary pump, as otherwise the difference of pressure between the outside and inside of the rotating drum will become sufficient to drive the gas back into the drum again.

In the past year, however, Dr. Gaede described an air-pump depending on a new principle, which he calls the molecular air-pump. Maxwell assumed, and Knudsen has recently verified experimentally, that if a gas be in contact with a solid surface, the gas molecules are reflected from it in all directions independently of the angle of incidence, or "diffusely reflected." This is due to molecular irregularities of the surface. Gaede has shown that for pressures above 0.001 millimeter of mercury the above assumption is not experimentally verified, and he attributes this to the formation of a film of adsorbed gas on the solid surface, which covers and conceals the molecular irregularities. The surface then presents only mechanical irregularities, and the result is that if a gas be traveling over a surface the molecules are preferentially thrown back in the direction from which they came, as they fall in general on small slopes of the irregularities facing their direction of drift. In both this case and that of diffuse reflection the new pump is effective, but the point is of interest in considering the theory of the pump, and it was considerations of this kind which led Gaede to its construction.

The new pump depends for its action on the dragging of the gas by a rapidly moving surface. Consider a

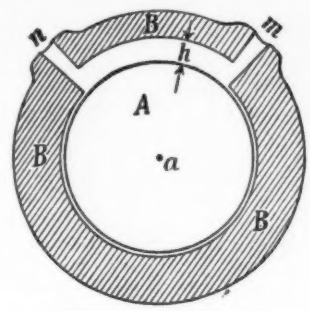


Fig. 1.—Simplified Section Through the Pump.

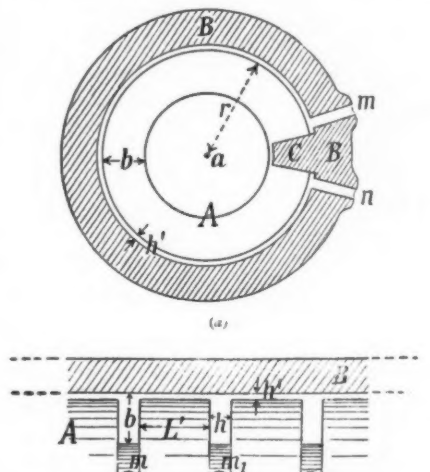


Fig. 2.—Actual Construction of the Pump.

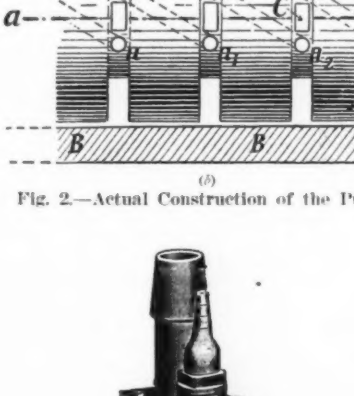


Fig. 3.—External Appearance of the Pump in Its Casing.

cylinder A rotating in a clockwise direction in a case B; in B there are two openings n and m connected by a slot (Fig. 1). The gas will be dragged by the cylinder from n to m, and in consequence a difference of pressure will be established between n and m which is proportional to the speed of rotation and the internal friction of the gas; the latter being independent of the pressure, the difference of pressure produced should be independent of the pressure. This is true when the pressure is relatively high; if it continued to be true down to the lowest pressures we should be able to create an absolute vacuum by exhausting initially with another pump at n to a pressure lower than the (constant) difference of pressure between m and n. When, however, we come to pressures below 0.001 millimeter of mercury this is no longer the case; the molecules are then diffusely reflected, and fly from one wall to the other without meeting other molecules. If the surface of the cylinder moved with a velocity greater than the molecular velocity we would obtain an absolute vacuum; such speeds are impossible in practice. However, at these low pressures the ratio of the pressures at m and n remains constant independent of the pressure, and it has been found that attainable speeds of revolution (8,000 to 12,000 revolutions per minute) are sufficient to give a vacuum better than any hitherto obtained.

In practice the pump is constructed as indicated in Fig. 2 (a) and (b). Instead of cutting the slot in the case, the cylinder is grooved, and a tongue C from the case projects into the groove; this is equivalent to a very long slot in the case. For increased efficiency several parallel grooves are cut, and connected with one another so that the low pressure side of one is the high pressure side of the next (Fig. 2, b). The complete pump is shown in Fig. 3. A preliminary pump is needed to reduce the pressure to a few millimeters of mercury initially.

A great advantage of this form of pump is that it deals with vapors as well as gases, as the low-pressure part of the pump remains at low-pressure. In other forms of pump the gases are compressed while being removed, and in consequence vapors condense which are afterward brought back into the vacuum again. Without drying agents the new pump has produced a vacuum lower than any hitherto measured, 0.0000002 millimeter of mercury; this pressure was calculated by observing the ratio of the pressures in different grooves.

Very interesting are the measurements made by Gaede of the kinetic heat effect. Owing to the increased velocity of the molecules the temperature of the gas should be higher near the upper surface of the tongue C (Fig. 2) than near the lower surface, and by arranging a thermocouple in place of the tongue C Gaede has detected such an effect as soon as the pressure is low enough to allow the mean free path of the molecules to be larger than the dimensions of the groove.

A table of the exhaustion attainable with various selected pumps is appended.

Pump.	Pressure in millimeters of mercury.
Water pump	10
Ordinary piston pump	1
*Older Geissler pump	0.1
*Newer Geissler pump	0.01
*Sprengel pump	0.001
*Modified Toepler pump	0.00001
*Kahlbaum's automatic mercury pump	0.000002
Geryk oil-filled pump	0.0002
Gaede rotary mercury pump	0.00001
Gaede molecular pump	0.0000002

* Taken from Winkelmann's "Handbuch der Physik," I. The numbers must only be taken as very rough; for instance, it is very doubtful whether Kahlbaum's pump can give a better vacuum than Gaede's mercury pump (the figure for which is given by the Physikalisch-Technische Reichsanstalt).

* Reproduced from *Nature*.

[1] Nobel discourse, 1906, p. 3.

A Strange Case of Abnormal Anatomy

A REMARKABLE case is reported from France. Drs. Podevin and Dufour presented before the Société Médicale des Hospitant a woman whose internal organs are completely reversed as compared with the normal right and left relation. Thus the apex of her heart is on the right of the median line, the liver is on the left. This subject reached the age of forty-two in ignorance of her strange condition, which was discovered only when she developed symptoms of appendicitis, not on the right, as any well-behaved patient should, but on the left! Her case has been examined by the aid of X-rays, after ingestion of eighty grammes of bismuth carbonate, which renders the structures in which it lodges opaque, without in any other way affecting the human economy. Incidentally, the patient is not left-handed, as might be supposed.

Ten Years of Government Irrigation Work*

A Review of the Activities and Experiences of the United States Reclamation Service Since the Passage of the Newlands Act

With the close of the last fiscal year the reclamation work of the U. S. Government rounded out its tenth year, thus making quite appropriate a review of the work done. Such a review will be published in the Eleventh Annual Report of the Reclamation Service, and through the courtesy of the director, Mr. F. H. Newell, the following extracts have been made from notes which have been used in part in the preparation of the report. The tables are taken from the recent report of the Secretary of the Interior.

OUTGROWTH OF FALLACIES.

In looking back over the history of the ten years it is interesting to note the outgrowth of many fallacies which were entertained when the work of the Reclamation Service was initiated. The first, and perhaps the most striking, is the idea concerning the low cost of reclamation by irrigation. The first settlers, acting singly or in communities, built comparatively cheap and temporary canals in the localities where the engineering problems were least difficult, and provided a supply of water which, without storage and without protection against floods, was frequently unreliable. The average cost per acre was estimated at an extremely low figure because of the fact that the actual cost was not recorded, and the acreage which might be irrigated was, as a rule, highly exaggerated—no allowance being made for imperfect water supply, nor for lands which for one reason or another could not be cultivated.

Another of the fallacies was in the assumption that as soon as water was provided this was practically the end of necessary expenditures. Little consideration was given to the large cost of leveling, subduing and cultivating the soil, and for providing the fertilizers which are necessary in an arid region. Because the arid lands contain certain mineral salts which in the East are sometimes useful as fertilizers it was assumed that the soil was necessarily fertile, not appreciating the fact that it frequently lacks the essential elements common in humid regions.

Another oversight in the earlier years was the neglect of full consideration of drainage and the importance of providing this to prevent much of the more valuable land from being destroyed by swamping, or alkali. To keep the lands in a condition of irrigability expensive drains must be provided.

It was not appreciated, also, that markets could not be had immediately for the crops raised, and that much time must be required in developing good markets and in discovering those crops or varieties which are most profitable under the existing conditions of soil, climate and transportation facilities.

But perhaps most important of all, it was not anticipated how difficult it would be to secure the right kind of farmers to handle the reclaimed land and utilize it to advantage. It was assumed that as soon as land was brought under irrigation there would be a rush of men, who would immediately cultivate every acre and begin the production of large and valuable crops. On the contrary, experience has shown that this is perhaps the most difficult part of the problem—far more so than the building of great structures.

When the act was discussed in 1901 and 1902 it was generally assumed that the principal operations would be those of constructing the larger reservoirs and main-line canals, leaving to the farmers the building of the distribution system. It was found, however, that this was not followed by the expected co-operation on the part of the settlers, and that to enable the lands to be cultivated it would be necessary to provide a complete system by which the water is taken to the vicinity of each farm.

The degree of completion of the works in other respects was found to be previously underestimated. Not only has it been found necessary to dig canals and laterals aggregating thousands of miles in length to reach each considerable body of irrigable land, but it was also found that a great number of structures must be provided which were not anticipated—for example, bridges or road crossings. Under ordinary pioneer conditions the settlers have either built the bridges and culverts or have endured the inconvenience of not having them. Where, however, the Government, or any large corporation, is building similar works this unfinished conditions is not tolerated by the community; every effort is made by the county and by all concerned to have strong, wide bridges, culverts and innumerable other structures, which are not so very expensive each in itself, but which together add greatly to the cost of the work, as each of these hundreds of structures must be carefully located and built for permanence.

It thus resulted that the original estimates based upon a few comparatively simple and large structures for storing and handling a considerable quantity of water have been revised from time to time at the request or demand of the settlers to include many extensions. Thousands of small, permanent structures, mainly of concrete and steel, and consisting of gates, measuring boxes, flumes, siphons, culverts and bridges, have been built. Had the people been content to take the water at a few points from the main-line canal and build these themselves, the expenditures by the Government would have been notably less, but, on the other hand, it would not have been possible to have brought under cultivation any considerable part of the land now reclaimed.

INCREASE OF COST.

The increase of cost of the works over the anticipated amount arises from two principal causes—first, because, as above stated, a very large number of additional structures have been provided; and, second, because of the increased cost of labor and materials. When the plans were made, during the four years from 1902 to 1905, prices were relatively low; since that date wages have increased probably 40 per cent or more, and materials and the cost of subsisting the men have increased in many cases upward of 60 per cent above the amount assumed in earlier years.

There are other factors which have led to increased cost over the early estimates—some of these being due to legislative and related causes. For example, the passage of the workmen's compensation act of May 30th, 1908, has added notably to the expenditures.

The rigid enforcement of the 8-hour act also tends to maintain the high cost. No discretion is left to the employer; frequently where half an hour of additional work would finish a job it is necessary to drop it and bring a gang of men from a distance, at considerable expense, to complete some minor detail, thus taking nearly half a day to do something which could have been finished in a relatively short time while the machinery was in full operation.

RELATION OF COST TO VALUES.

Although the cost per acre irrigated is considerably greater than was anticipated at the time of the passage of the Reclamation Act, yet this has been accompanied by an equal, or even greater, increase in value of results; so that if the acreage cost of irrigation has been doubled, it may be claimed that the value received has been trebled. This is due to the general increase in prices of lands and of agricultural products, as well as of labor and materials.

The fact that there has been such increase is shown by the growth of prices asked for the raw lands under both public and private projects. At the time the Reclamation Act was passed the reclamable lands could be had at a nominal value—a little more than the cost of keeping the title and procuring the conveyance, or upward of $5 an acre. Within the ten years subsequent to that time the asking price of these lands has not improved in any way, except by the building of the works by which water might be got it has jumped to from $50 to $100 or more per acre. In some cases the prices asked for the raw land have increased 1,000 per cent. It is this unearned increment which is really the great load which is holding back the rapid development of irrigated lands in the West, whether watered by the use of public or private capital. It has stimulated the work in one way, and at the same time has developed a class of men who are largely interested in getting a piece of land in the hope of selling a relinquishment of title. They have found that the profits from simply holding the irrigated lands out of the market are greater than those from utilizing these lands in the production of crops; the second or third comer, who may be the real farmer, thus has to incur not only the cost of clearing, leveling and subduing the soil, adding improvements and paying for the water supply, but, in addition, has the burden, equaling or exceeding the other costs, of paying for the unearned increment charged for the land.

AMENDMENT TO THE ACT.

The amendments to the Reclamation Act have been relatively simple. Probably the most important of these amendments is that of June 25th, 1910, relating to advances to the Reclamation Fund. An advance or appropriation of $20,000,000 was made, under the terms of the above-noted amendment; to complete the reclamation projects and such extensions as may be deemed necessary for the successful operation of the works; also, to protect water rights claimed by the United States. This appropriation is in the nature of a transfer to the Reclamation Fund, and can be called upon only as needed to make payments for works performed under existing law. These sums so transferred are to be reimbursed from the Reclamation Fund, the proviso being added that no part shall be expended upon any existing project until it shall have been examined and reported upon by a board of engineer officers of the army designated by the President, and approved by the President as feasible and practicable, and worthy of such expenditure; nor shall any portion be used on any new project.

The requirement of actual residence upon the land or in the vicinity has led to some hardships to individuals because of the fact that, as soon as survey parties appeared in the field, men rushed in and took up land, often wholly in ignorance of the probabilities of reclamation. These men, in order to obtain title to the lands, have been compelled to live with their families in the desert, awaiting the development of other areas. This condition was anticipated at the time of the passage of the act, and the attempt was made to exclude settlement until the works were built. This was opposed on the ground that no intelligent man would think of attempting to make settlement in a desert until the water was actually in sight.

The need of this requirement of actual settlement is based upon the fundamental conception of the objects of the act. It is not enough to simply reclaim the land; this may add to the material prosperity of a few, but it does not produce citizenship. Unless settlement is required a man in a neighboring State may take up a desirable farm, have it irrigated at the expense of the Government, put a tenant on it, and thus defeat the principal motive of the law, namely, the development of a self-supporting citizenship.

All attempts at modifying this provision regarding residence have been opposed because of the fundamental consideration. The events of the past ten years have shown the wisdom of this, as under the private projects where residence is not required the developments have been very largely along the line of the creation of tenant farms.

SIZE OF UNIT.

Another of the features of the act which has been subject to criticism is that limiting the area of reclaimed land to the acreage which, in the opinion of the secretary, may be reasonably required for the support of a family. Nearly every settler desires to obtain as much land as he can because of the hope of obtaining the unearned increment in value of this land. As a consequence, nearly every one attempts to hold at least 160 acres, and to scatter his improvements over the entire area. He even tries to hold additional lands in the name of some near relative or friend. The result is that, with scanty capital, he is not able to level and subdue all of the land and bring it to a profitable state of cultivation. It frequently happens that a man who would be prosperous on 40 acres fails on 160 acres. The result is not only disastrous to him, but to the project as a whole, and to the object of the law, in that he is unable to produce profitable crops, and thus deprives others of the benefits that would accrue if he made his payments promptly and the money was used over again to reclaim other lands.

The strongest pleas for the extension of the time of repayment and for the amelioration of the conditions come from men who are vainly trying to cultivate more land than they can successfully handle; they assert that the expenses are too great and that they must have relief. In a number of instances where men have had possession of areas upon which they were making failures it has been advantageous to cut the unit in half. If any errors have been made in the past they have been more apt to be on the side of liberality in the size of the units. In few, if any, instances have these proved to be too small—even when set at 20 acres.

PRESENT INVESTMENT.

The total amount expended to June 30th, 1912, is $72,000,000. This may be considered under two heads—first, the investment in works which are practically completed and from which returns are being received, and, second, the investment in portions of the works which cannot be utilized until more work is done. Table 1 gives the investment to June 30th, 1912.

The degree of completion of the works, and of their utilization by settlers, is most completely shown by the crop returns and by comparison of these with simi-

* Reproduced from *The Engineering Record.*

ilar figures for all other irrigation works. It is to be noted that the average of these crop returns is far less than should be the case with better cultivation—this being due to the newness of the land, lack in many cases of fertilizers and the inexperience of the majority of the irrigators. Each year the lands, as a whole, are being improved; but this is not conspicuously shown in the average crop values, because each year more new land is brought under cultivation, thus reducing the average.

The average crop value, as shown in Table 2, for 1909, was $29.10; in 1910 it dropped to $27.50, and in 1911 to $23.30. This reduction in the average is due to the rapid increase in the number of farms and in the acreage irrigated, and probably to greater accuracy in the returns. It is not believed that it indicates any deterioration in the land as a whole, although there has been a gradual increase of area of swamped lands due to excessive use of water on the newer farms. There is a tendency for the better land lying along the streams to decrease in crop production unless protected by careful drainage and handled in the best method.

ECONOMICAL USE OF WATER VITAL.

The average value of crops per acre in 1909 on irrigated land for the whole arid West, as shown by the census for 1910, is about $25; so that it may be said

TABLE 1—INVESTMENT IN RECLAMATION PROJECTS TO JUNE 30, 1912

State	Project		Net investment
Arizona	Salt River		$9,641,595.53
Arizona-California	Yuma		5,765,285.71
California	Orland		554,871.74
Colorado	Grand Valley		101,415.11
do	Uncompahgre		4,780,191.11
Idaho	Boise		6,958,350.90
do	Minidoka		4,101,817.31
Kansas	Garden City		380,527.20
Montana	Huntley		886,958.50
do	Milk River		1,004,309.63
do	Sun River		863,581.50
Montana-North Dakota	Lower Yellowstone		3,041,709.27
Nebraska-Wyoming	North Platte		5,438,721.92
Nevada	Truckee-Carson		4,571,653.62
New Mexico	Carlsbad		692,154.57
do	Hondo		353,962.44
New Mexico-Texas	Rio Grande		880,797.49
North Dakota	Pumping		873,896.11
Oregon	Umatilla		1,293,667.04
Oregon-California	Klamath		1,990,902.24
South Dakota	Bellefourche		3,083,149.11
Utah	Strawberry Valley		1,826,481.07
Washington	Okanogan		556,642.31
do	Yakima		5,488,921.52
Wyoming	Shoshone		3,691,608.61
Total primary projects			$68,823,171.56
Secondary projects			586,992.94
Arizona-California, Colorado River			43,709.23
Oklahoma, Cimarron			9,128.92
Oregon, Central Oregon			40,391.67
Townsite development			15,677.85
General			32,902.54
Indian:			
Blackfeet, Montana		$143,503.64	
Flathead, Montana		152,625.36	
Fort Peck, Montana		10,113.22	
			306,242.22
Total			$69,858,216.93

TABLE 2—OPERATION AND MAINTENANCE RESULTS, 1909, 1910 AND 1911

	1909 20 Projects	1910 22 Projects	1911 23 Projects
Area irrigated:			
Under water-right applications, acres	176,942	208,318	270,459
Under rental contracts, etc., acres	233,686	265,105	297,937
Total irrigated, acres	410,628	473,423	568,396
Total number acres irrigable	730,601	917,751	1,015,494
Number of farms irrigated	9,503	11,676	13,708
Number of water-right applications	3,657	5,325	9,528
Number of miles of canals operated	2,993	3,945	4,853
Cost of operation and maintenance:			
Total	$936,433	$981,966	$1,058,238
Per acre	$2.28	$2.07	$1.88
Value of crops:			
Total	$11,920,663	$12,974,639	$13,121,224
Per acre	$29.10	$27.50	$23.30
Population of farms	53,812	63,149	69,638
Quantity of water diverted to land:			
Acre-feet	1,523,638	1,655,696	2,079,033
Per acre	3.7	3.5	3.7

that the results obtained on reclamation projects are fairly comparable with those prevailing throughout that section of the country. Without going into a careful analysis of the crops it may be stated that the returns show that for ulimate success a more economical use of the water is vital. This must be accompanied by more thorough cultivation and the introduction of special crops adapted to the soil, climate and markets. The tendency has been to adhere too closely to the old methods of agriculture and to the ordinary field crops, which cannot be produced under irrigation with the same degree of success as is possible with improved varieties.

The first effort of the irrigator on new lands, after

TABLE 3—CROP ACREAGE, 1911

Crop	Acreage	Per cent
Alfalfa	253,576	42.0
Barley	28,320	4.7
Beans	1,589	0.3
Beets	8,214	1.4
Cane (sugar)	343	0.1
Corn	14,177	2.3
Cotton	3,606	0.6
Flax	2,156	0.3
Fruit	42,143	7.0
Garden	3,994	0.7
Hay (clover, timothy, etc.)	19,432	3.2
Hops	417	0.1
Melons and cantaloupes	2,841	0.5
Oats	55,007	9.1
Onions	197	0.0
Pasture	47,128	7.8
Potatoes	14,985	2.5
Rye	2,124	0.4
Sorghum	1,189	0.2
Speltz	904	0.2
Wheat	76,472	12.7
Miscellaneous	23,732	3.9
Total	602,546	100

these have been leveled and put in good condition, is to grow alfalfa, or some similar plant of the clover or pea family, which will put nitrogen into the soil. It is necessary to spread a blanket of alfalfa over the surface and then to turn the plants under the surface, in order to supply organic matter to the soil. Table 3 shows the acreage of the principal crops raised and the percentage of the total acreage represented by each. There is, of necessity, some duplication in these figures, as some of the land is in orchard and is cultivated between the rows, and in other cases more than one crop per year has been produced.

The continuation of reclamation work in the future is dependent upon the success of the farmers on the land and their ability to make the payments, enabling funds to be used over again. Future operations rest on the effective efforts of the farmers; they can easily discharge their debts to the Government if they can raise sufficiently large crops and obtain a good market for them. On the other hand, failure on the part of the majority of the farmers to practice economy of water, to thoroughly cultivate the soil and to plant the best varieties of crops must be followed by inability to discharge the debt and in corresponding delay in extending the irrigated areas in accordance with the needs of the growing West.

Table 4 contains a summary of the results of the work from the time of the passage of the Reclamation Act on June 17th, 1902, to June 30th, 1912.

TABLE 4—SUMMARY OF RESULTS TO JUNE 30, 1912

Area, all projects when completed	acres	3,020,689
Area for which water is ready	acres	1,168,530
Area receiving water under permanent contracts	acres	452,132
Area receiving water under temporary contracts	acres	383,572
Reservoir capacity	acre-feet	4,833,070
Canals:		
Capacity over 800 sec.-ft.	miles	310
Capacity 301 to 800 sec.-ft.	miles	454
Capacity 50 to 300 sec.-ft.	miles	1,083
Canals and drainage ditches, capacity less than 50 sec.ft.	miles	5,507
		7,354
Number of tunnels, 72; length, 113,534 ft.	miles	21.5
Storage dams, volume 7,795,346 cu. yd.		
Diversion dams, volume 912,961 cu. yd.		
Dikes, volume 3,553,000 cu. yd., 80 miles.		
Canal structures costing:		
Over $2,000		568
$500 to $2,000		1,142
Less than $500		33,398
Total		35,108

Bridges: Number, 2,908; length, 61,300 feet.
Buildings: Offices, 70; residences, 379; others, 346; total, 786.
Roads, 659 miles. Railroads, 44 miles.
Telephone lines: Miles, 2,118; phones, 838.
Transmission lines, 311 miles.
Material excavated: Class I, 79,790,814 cu. yd.; Class II, 6,037,065; Class III, 4,846,402; total, 90,674,381.
Riprap: 377,407 cu. yd.; paving, 439,940 sq. yd.
Cement, 1,389,555 barrels; concrete, 1,157,507 cu. yd.
Cement manufactured by United States, 338,452 barrels.
Pipe: Concrete, 395,553 ft.; tile, 35,733 ft.; steel and iron, 28,483 ft.; wood, 171,017 ft.; total, 630,786 = 120 miles.
Flumes: Concrete, 2,424 ft.; steel, 59,207 ft.; wood, 303,848 ft.; total, 365,479 ft. = 69 miles.

Experimental Psychology and Medicine*

By H. L. Hollingworth, Ph.D., New York
Department of Psychology, Columbia University

FROM the point of view of method and from the point of view of content what have been the psychological contributions to law and medicine, and what further serviceableness may we reasonably expect? I may say at once that in so far as law and medicine have profited from their utilization of psychology, this profit has been chiefly by way of methodology and technique. In so far as there has been any interchange of content, psychology has been far more greatly blessed in her receiving than in her giving. Medical clinics and legal practices have been drawn on freely for data, problems, suggestions, and illustrations, and psychology still shows, in many quarters, pronounced anatomical, physiological, and clinical leanings.

It has seemed to me that the contributions of psychology to medicine may be presented under five chief headings. I shall briefly point out these five groups, illustrate them, and indicate whether the contribution is chiefly of content or of method.

I. *Psychological Researches on Patients.*—Three subdivisions may be pointed out here:

(a) The mental and motor behavior of patients, as studied by psychology, reflects their organic condition. Knowledge of this condition may be useful to the physician, particularly if it is a nervous disorder that is involved. As an illustration of this type of work I may refer to the recent studies by Dr. F. Lyman Wells, of McLean Hospital, on the behavior of maniac-depressive patients in such performances as speed of tapping, speed and quality of association, sensory discrimination, discrimination, etc. Interesting correlations are found between performance in the tests and organic condition at various times in the history of the case.

(b) Knowledge of the normal types and range of variation in mental processes may prove of great assistance in diagnosis of supposedly abnormal cases, and may be of general use in clinical procedure. As illustration of this field I may cite the work of Kent and Rosanoff on the association reactions of normal and abnormal individuals. A list of 100 test words was arranged, and the free associations to these 100 stimulus words, in the case of 1,000 normal people, were experimentally determined. When the character of these associates was studied it was found possibie to make out normal tendencies in the case of each stimulus word, and also a normal range of variability within this tendency. When these associations were classified according to quality, under such headings as rhyme, neologism, perseveration, individual reactions, etc., the association types of normal people could be made out. The same test words were then given to 247 patients, suffering from the various forms of insanity, and these associations similarly studied. Comparison of these results with the results secured from normal subjects, enabled the investigators to draw such conclusions as the following: "With the aid of the frequency tables and the appendix normal reactions, with a very few exceptions, can be sharply distinguished from pathological ones. The separation . . . simplifies the task of analysis and makes possible the application of a classification based on objective criteria. . . . In dementia præcox, some paranoic conditions, manic-depressive insanity, general paresis, and epileptic dementia the test reveals some characteristic, though not pathognomonic, associational tendencies." Further studies of this sort are in progress; they are at once thoroughly psychological and medically useful.

(c) Psychological examination may often be valuable in measuring or demonstrating the efficacy of various treatments for abnormal physical condition. I may give by way of example the psychological examination of hook-worm patients now being made by Dr. E. K. Strong. By a series of tests Strong is measuring the mental alertness and capacity of children who are about to be placed under treatment. At the same time he examines in the same way a control group of healthy children living under the same general conditions. After the treatment both groups of children are to be re-examined by the psychological tests and determination made of such change in mental condition as may be produced—in the normal group by mere repetition and normal growth, and in the abnormal group by these factors plus medical treatment for the disease.

These three subdivisions constitute my first heading, "Special Researches on Patients." Such contribution as psychology may be making to medicine in this field of work is chiefly a contribution of content. But the psychological content is used by the medical man merely to reinforce or supplement his own methods and technique.

II. As a second general heading I suggest "*The Psychological Researches on the Influence of Drugs on Mental and Motor Processes.*" Here medicine must be said to owe a great deal to psychology. And the chief contribution has been by way of perfected methods. By way of illustration one need only compare the unreliable, roughly made experiments of Kraepelin and his earlier students with recent work by Rivers and with certain rigorously controlled investigations which have been carried on in my own laboratory. The trouble with the earlier workers was that they knew too little about psychological laws, psychological sources of error, and the technical cautions which must be observed in conducting crucial experiments on mental and motor reactions. Later workers have been more familiar with these factors, and they have drawn their knowledge not at all from the field of pharmacology but directly from the psychological laboratory. Four points may be noted as especially important in the improvement of scientific technique in drug experimentation.

(a) *The importance of controlled conditions.* This is, of course, a most obvious factor. However, in many sciences the general conditions are so stable and uniform that many of them may be practically disregarded for

*Abstract of a paper read before the Society of Medical Jurisprudence.

the purposes of a simple experiment. Thus the temperature of the room, the day of the week, the noon-day menu, the sex of the operator, and a hundred other conditions are irrelevant to the outcome of an experiment in physics. But in a psychological experiment these factors play an important rôle. One need go back only so far as the time of Kraepelin's drug experiments to find men investigating the influence of tea and coffee in the evenings of days on which the subjects of the experiments had taken both strychnine and alcohol, experimentally, at an earlier hour. We now know, and partly as the result of work done in psychological laboratories, that the primary influence of so mild a drug as caffein may persist for twenty-four hours or more.

(*b*) A second important point in technique, the recognition of which is at least in part due to the influence of psychological methods, is the *necessity of a control squad.* You may recall the account of the control group of normal children in the case of the experiments with the hookworm children. In the case of my own experiments on the influence of caffein, a control squad ran through the entire experiment, covering a period of six weeks, taking daily doses, along with the other subjects. But these doses, although this was known to no one but the director of the experiment, consisted of nothing but sugar of milk. This is of course only another point under the general one of controlling the conditions, and it enables the investigator to compare his drug records with records of undrugged subjects acting under the same conditions of practice, excitement, suggestion, interest, ennui, fatigue, diurnal variation, etc. This again is a most obvious point, yet only a year ago I heard a medical expert of repute assert that a certain drug produced congestion of the cerebral blood vessels, because an animal which had been fed on this drug was found to have congested cerebral vessels after having been killed by a blow on the head. A control animal, which should be struck on the head but not fed the drug, seemed not to have been even considered, although the experiment was deliberately planned and in an important connection.

(*c*) The *importance of control doses* may also be pointed out. The medical experiments on drugs, until within quite recent years, proceeded by administering, at a known time, a known drug to a subject who was aware of the whole situation, and who had his own prejudices and opinions, was open to all manner of suggestion, and who was at any rate more or less interested in the outcome of the test, and, perhaps, excited at the thought of taking the drug in question. Yet any change in performance, under these gross conditions, was likely to be attributed to the direct action of the drug. It was not until Feré, a psychologist, demonstrated the stimulating effect of the mere act of swallowing, or, indeed, of simply holding a drink of whiskey in the mouth, thus getting odor, taste, and any conceivable amount of suggestion, excitement, etc., and until Rivers, another psychologist, wrote his illuminating paragraphs on the technique of drug experimentation, that medical experimenters came to realize the importance of the two factors of sensory stimulation and suggestion.

(*d*) The fourth point in technique is concerned with the *standardization of tests.* Many of the tasks set the subjects of drug experimentation before the psychologists addressed themselves to the standardization of series of tests for definite functions or processes, measured processes which varied not only from individual to individual but even from moment to moment or from day to day with a single individual. The much-used cancellation test is an instance of such an ambiguous task. It must be said that a great deal remains to be done in the way of standardization of tests, but the point to be made here is that it is work which must be done by psychological workers, and which when done, will represent a valuable contribution to the equipment of medical workers.

III. As a third general topic I may mention *Psychanalysis.* Here again, so far as psychanalysis is a contribution of psychology, it is purely methodological in character. The psychanalysts proceed on the assumption that emotional experiences and complexes, which persist in an unclear or subconscious way—fears, wishes, etc.—are nevertheless active determinants of action, thought, and feeling. They act chiefly as disturbers; they disturb our sleep by dreams; they disturb our daily life by producing phobias, obsessions, dissociations, amnesias, slips of hand and tongue, etc. Furthermore, by the simple association experiment, skillfully conducted by an experienced analyst, it is claimed that these complexes may be discovered, brought into clear consciousness, and dissipated, and the sufferer thereby relieved. The work of Freud, Jung, Janet, Brill, Jones, and others may be cited here. It must be said that psychologists are by no means unanimous in their reaction toward the claims and interpretations of the psychanalysts. But the lack of unanimity of individual psychologists is one of the things that makes the science interesting. We must say at least that in so far as psychanalysis throws genuine light on the causes, conditions, and prognosis of functional disorders, and in so far as its utilization affords relief which ordinary therapeutic measures fail to give, it represents a real contribution to medical science. And it, again, is chiefly a methodological contribution.

IV. *The Use of Psychological Agents* (Psychotherapy).—This fourth general topic is one on which I might be expected to dilate at great length. It is the one about which most has been written, and which is, I think, quite commonly supposed to constitute the most important direction in which psychology may contribute to medicine. But it seems to me to be, at the present time at any rate, one of the minor issues. Suggestion, hypnotism, re-education, synthesis, clarification of complexes, association, and dissociation are the words which come to all of you as I read. That some of them are psychological words there can be no doubt. That they represent genuine mental processes, states, or functions, and that psychologists are interested in discovering and formulating their laws, must be granted. But it is equally certain that no little obfuscation has been caused by pseudoscientific writers who have attempted to arouse dramatic interest in certain phenomena of fatigue, automatism, drowsiness, and hysteria, and have drawn into their service in this attempt the occult suggestions which formerly emanated from the words suggestion and hypnotism. As for the terms re-education and synthesis, they are not, properly speaking, psychological at all, but represent large and practical processes, with little attempt at psychological analysis, description, or formulation. And as for the last two processes, association and dissociation, psychology has done little more than incorporate in its own literature fragmentary clinical pictures and speculations indulged in by medical investigators. The processes intended by the words suggestion, re-education, synthesis, etc., in the books on psychotherapy really move on the same plane, psychologically, as do such expressions as: Lend a helping hand, give direction, set a good example, give encouragement, provide an incentive, take a little exercise, arrange for new surroundings, jog the memory, etc. All of these phrases, it is true, emphasize the mental functions of a psychophysical organism rather than its physiological processes. This emphasis is, perhaps, responsible for the first two syllables of "psycotherapy." And it follows, of course, that acquaintance with the laws of mental and motor behavior and with the elements, attributes, patterns, and genesis of mental processes is favorable to satisfactory work on this plane, as it is also in teaching children, hunting wild beasts, and selling goods. My point is that the use of these psychological agents does not require any very profound knowledge of the refinements of modern psychology—the contribution of psychology to medicine at this point is not specific in character, but is rather the general contribution to which I referred earlier in this paper. I feel impelled to add that the contribution here will become more and more specific when psychology begins to occupy itself more with *the way in which mind works*, and less with *what is in the mind* at the moment of its operation.

V. The fifth and final field in which I seem to find psychology making specific contribution to medicine may be designated *Determination of the Organic Conditions of Efficiency.* The contribution here is peculiar in that it may often appear to be but a contradiction of the deliveries of medical science. I shall call your attention to but two subdivisions of this general topic—fatigue and periodicity.

The investigation of muscular fatigue is so near the border line of physiology and psychology that little need be said of it here. Perhaps the one important point is the fact that psychological studies tend constantly to emphasize the importance of purely mental factors in the production of supposedly muscular inefficiency; such factors as ennui, loss of interest, the inhibitory action of sensations of strain, habit, and the general level of fatigue sensation, etc. The distinction between actual exhaustion and mere cessation of work because of psychic inhibition, a distinction constantly exemplified during psychological investigations of fatigue and work, would seem to be important in medical diagnosis and therapeutics.

With respect to mental fatigue, the net outcome of psychological studies up-to-date is that the more muscular fatigue is eliminated from a given task the more unfatigueable does the process become. This is often expressed by saying that purely mental fatigue has never been satisfactorily demonstrated. Of course, it is also true that no purely mental process has ever been isolated. There seems to be little doubt that by the co-operation of medical science with psychological investigation information may ultimately be secured concerning the nature and causes of fatigue which will be of service to both fields of work.

My general conclusion is that the chief contribution which psychology has made and may be expected to continue to make to medical science is methodological in character. There seem to me to be two principal reasons for this:

In the first place, the experience and training of the medical student are largely clinical. This means th his observation is for the most part of pathological co ditions. He may easily fail to acquire sufficient inform tion concerning normal types and the direction, cond tions, and range of normal variability. Such knowledg which might well be partially furnished by adequa psychological training, might at least warn him of t fallacy of generalizing clinical findings.

In the second place, the medical course as it is n offered seems to provide little training in exact and pu posive experimentation. An excessive proportion of th student's time seems to be occupied with the memori of anatomical minutiæ, the most of which are straigh way forgotten, the disciplinary value of which is at le questionable, and the content of which is always acce ble in the manuals. It seems to me, for these reaso that one of the most fruitful contributions which ps chology may *yet* make to medicine may be a rigoro specially adapted full-year course in experimental ps chology, which should be incorporated at an early poi in the curriculum of the medical school. The content such a course should be determined largely by medi men, but much stress should be laid on methods a technique of arriving at experimental certainty, avoidi logical fallacies and inductive errors, and of adequate controlling the grounds of inference under circumstance in which very slight factors may play important rôles.

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SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

NEW YORK, SATURDAY, MARCH 1, 1913

Published weekly by Munn & Co., Inc., Charles Allen Munn, Preside
Frederick Converse Beach, Secretary and Treasurer;
all at 361 Broadway, New York

Entered at the Post Office of New York, N. Y., as Second Class Matte
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Scientific American (established 1845) . . . . "
American Homes and Gardens . . . . "

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